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Journal
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The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 195 MAY, 1923 No. 5

THE ELECTRON IN CHEMISTRY.*

BY

SIR JOSEPH JOHN THOMSON, O.M., F.R.S., LL.D., Ph.D., D.Sc.

Master of Trinity College, Cambridge, England,
Franklin Medallist, Honorary Member of the Institute.

I OUGHT to explain why it is that I, who am a physicist and not a chemist, have chosen chemistry as the subject of these lectures. I have done so because I believe that the introduction of the idea of the electron will break down, and indeed has already done so to some extent, the barrier of ignorance which has divided the study of the properties of matter into two distinct sciences, physics and chemistry. The properties of matter which are of primary importance to the chemist are those which relate to the power of atoms to unite together to form new combinations, new compounds. The ability to do this and the type of compound formed vary enormously from one chemical element to another. Until recently the conception formed by the physicist of the atom afforded no clue to this variation in the chemical properties of the atom and gave therefore but little guidance to the chemist in what he regarded, and quite rightly, as the most important part of his work. The chemist wants to know much more about the difference between an atom of hydrogen and one of oxygen than that the atom of hydrogen is a small particle of one kind of matter and

* A series of lectures given before The Franklin Institute, April 9–13, 1923, see page 724.

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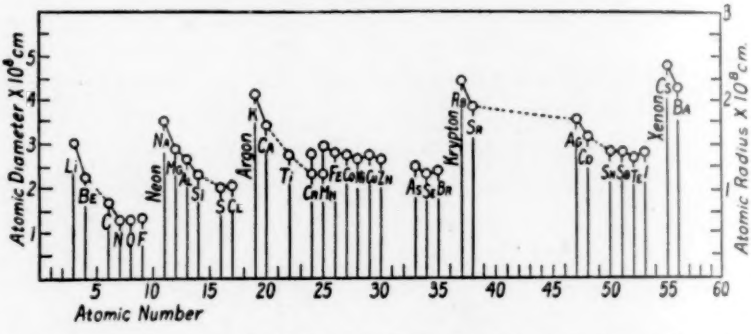
the atom of oxygen a heavier particle of another kind of matter. This lack of knowledge led to a proposal made by a distinguished chemist at the beginning of this century to give up the atomic theory and base chemistry on statistical and thermodynamical considerations.

The chemist wants to know the reason why the behaviour of an atom of hydrogen is so different from that of one of oxygen. This must depend upon the differences in the constitution of the two atoms themselves. Thus to explain the difference between the chemical properties of different atoms we have to go a stage further than the atomic theory. Just as some of the physical

FIG. 1.



properties of matter in bulk had required for their explanation the conception that matter is not continuous but has a structure of finite and measurable fineness, so no progress could be made towards the explanation of their chemical properties until we gave up the idea that the atom was indivisible, continuous and uniform, and assigned to atoms as well as to solids and liquids a structure of their own. The discovery of the electron in 1897 was the first direct evidence of such a structure. It was shown that these electrons came from all types of atoms, and that whatever the source there was only one kind of electron, which has a mass only about 1/1700 that of an atom of hydrogen and carries a charge of negative electricity numerically equal to the positive charge associated with an atom of hydrogen in the electrolysis of solutions.

Thus an invariable electron was proved to be a constituent of all atoms. Means were then devised to measure the number of electrons in the atoms of the different chemical elements. It

was found that this number was finite and varied from element to element, and that the number of electrons in the atom of an element was equal to the atomic number of the element: The atomic number of an element being its place in the list when the elements are arranged in the order of their atomic weights. As the atomic number is roughly proportional to the atomic weight the proportion between the mass of the electron and the total mass of an atom is, except for hydrogen, much the same for all atoms. The electrons, however, only account for about 1/3400 of the whole mass, for most purposes a negligible fraction.

The greater part of the mass is accounted for by the positively electrified part of the atom. The electrons are all negatively electrified and as the normal atom is electrically neutral, there must be within it a positive charge to balance the negative one on the electrons. This positive charge, as experiments on positive rays show, is attached to a mass equal to the mass of the atom. Thus the carrier of the positive charge, unlike that of the negative, varies from element to element. As the mass of the positive charge is always an integral multiple of a unit, it is natural to suppose that this mass is made up of a number of units bound together. The number of such units is equal to the atomic weight and the number of electrons approximately half that number, if each unit of mass carries the atomic charge of positive electricity, the quantity of positive electricity would be too large unless these positive units were associated with about half this number of electrons. Thus, in addition to the structure conferred by the electrons, the positively electrified parts have themselves a structure, it is the structure conferred by the electrons which is responsible for the chemical properties of the atom, the structure of the positive core is concerned with radioactive transformations.

As up to the present nothing has been discovered that cannot be resolved into electrons and positively electrified particles, it is natural to frame a theory of the structure of the atom on the supposition that it is built up of these two ingredients. It should be borne in mind, however, that our means of detecting the existence of electrically charged bodies far surpass those for detecting uncharged ones, and if there were any uncharged constituents of the atom, they would in any case probably have escaped detection. We know, however, even supposing that such constituents do exist, their mass must be negligible compared with that of the positive

parts, for these parts account for well within a fraction of a per cent. of the whole mass of the atom.

ARRANGEMENT OF ELECTRONS IN THE ATOM.

Confining ourselves then to the consideration of things whose existence has been demonstrated we regard the atom as made up of a massive positively electrified centre surrounded by electrons. The number of electrons increasing from one in the atom of hydrogen to a hundred or more in the heavier elements. The positive charge of the centre and the negative charges on the electrons will produce a field of electrical force which will be determinable when the position of the electrons can be specified. Thus the force exerted by the atom and therefore its chemical properties will depend upon the configuration of the electrons and to determine this is one of the most important problems in the electron theory of chemistry.

This problem is that of determining the way the electrons will arrange themselves under the action of their mutual repulsions and the forces exerted upon them by the positive charge.

In the first place we observe that if these forces were to vary strictly as the inverse square of the distance we know by Earnshaw's theorem that no stable configuration in which the electrons are at rest or oscillating about positions of equilibrium is possible, the electrons must describe orbits, and further they must describe different orbits; for such a system as that in Saturn's rings where several units follow each other round the same orbit is not possible when the units, as the electrons would do, repel each other instead of attracting one another like the constituents of Saturn's rings. When there are several electrons in the atom the orbits described by the electrons would be of great complexity, and the mental picture conveyed by this multitude of orbits would be too blurred and complicated to be of much assistance in helping us to get readily a clear idea of what is going on in chemical processes.

I have therefore adopted the plan of supposing that the law of force between the positive part and the electrons is, at the distances with which we have to deal in the atom, not strictly that of the inverse square, but a more complex one which changes from attraction to repulsion as the distance between the positive charge and the electron diminishes. This hypothesis leads to a simple mental picture of the structure of the atom and its conse-

quences are in close agreement with the facts of chemistry. I suppose that the repulsive force between two *electrons* is always inversely proportional to the square of the distance. With regard to this point I may point out that we have no direct evidence as to what may be the law of force between electrical charges at distances comparable to 10^{-8} cm., which is a distance which we have reason to believe is comparable with that which separates the positive charge from the electron in the atom. The direct experimental verification of this law has been of course made at incomparably greater distances, while the direct experiments, such as those on the scattering of the alpha particles, only give information as to the law at distances very small compared with 10^{-8} cm.

I shall assume that the law of force between a positive charge and an electron is expressed by the equation

$$F = \frac{Ee}{r^2}\left(1 - \frac{c}{r}\right) \qquad (1)$$

where F is the attraction between the charges, E, e, the positive and negative charges on the core and electrons, respectively, r the distance between them and c is a constant varying from one kind of atom to another, it is the distance at which the force changes from attraction to repulsion and is of the order of 10^{-8} cm.

We may remark in passing that the introduction of some new physical law, involving directly or indirectly a length of this order, is necessary for any theory of the structure of atoms. We could not form a theory at all if all we knew about the action of electric charges was that they repelled or attracted inversely as the square of the distance, for this would put at our disposal only two quantities, the mass of an electron and its charge, and so could not furnish the three units of space, mass and time required for any physical theory. The discovery of the induction of currents or what is equivalent, the magnetic effect due to electric charges, introduced another fundamental unit the velocity of light; the unit of length to which this system leads is the radius of the electron, about 10^{-13} cm., a quantity of quite different order from 10^{-8} cm., which corresponds to atomic dimensions. The size of atoms being what it is, is a proof that there is some law of physics not recognized in the older science which is all-important in connection with the theory of the atom and must form the basis of that theory.

If the law of force is that just given, then a number of electrons can be in stable equilibrium around a positive charge without necessarily describing orbits around it.

ONE ELECTRON ATOM.

Thus, for example, if there is one electron it will be in stable equilibrium at a distance c_1 from the positive charge.

TWO ELECTRON ATOM.

If there are two electrons they will be in equilibrium with the positive charge midway between them, r the distance of either electron from the positive charge is given by the equation

$$\frac{Ee}{r^2}\left(1-\frac{c_2}{r}\right)=\frac{e^2}{4r^2} \qquad (2)$$

When the positive charge and the two electrons form an electrically neutral system $E=2e$, so that $c_2/r=7/8$ or $r=1.14\ c_2$.

THREE ELECTRON ATOM.

When there are three electrons, they will be in equilibrium at the corner of an equilateral triangle with the positive charge at the centre. r, the distance of any electron from the centre, is given by the equation

$$\frac{Ee}{r^2}\left(1-\frac{c_3}{r}\right)=\frac{2}{3r^2}\cos 30 \qquad (3)$$

When the system is electrically neutral $E=3e$, so that $r=1.26\ c_3$.

FOUR ELECTRON ATOM.

The most symmetrical arrangement of four electrons is when they are at the corners of a regular tetrahedron. The distance of the electrons from the centre when the atom is neutral is equal to $1.29\ c_4$. The tetrahedron may be regarded as the ends of two equal lines at right angles to each other and also to the line joining their middle points.

FIVE ELECTRON ATOM.

Five electrons are in equilibrium when arranged so that three are at the corners of an equilateral triangle, the other two at the ends of a line passing through the centre of the triangle and at

right angles to its plane; the line is bisected by the plane of the triangle. The distance of the electrons in the triangle from the centre is 1.34 c_5, that of the other two 1.37 c_5.

SIX ELECTRON ATOM.

Six electrons are in equilibrium when at the corners of a regular octahedron. For some purposes it is convenient to regard the octahedron as two equilateral triangles at right angles to the line joining their centres, one triangle being twisted relatively to the other so that the projection of their corners on a parallel plane forms a regular hexagon. The distance of the electrons from the centre is 1.38 c_6.

SEVEN ELECTRON ATOM.

Seven electrons arrange themselves so that five are at the corners of a regular pentagon while the two others are at the ends of a line through the centre at right angles to the plane of the pentagon and which is bisected by that plane. The distance of the electrons in the pentagon from the centre is 1.4 c_7, that of the other two 1.37 c_7.

EIGHT ELECTRON ATOM.

Eight electrons arrange themselves at the corners of a twisted cube, a figure obtained by taking two squares, placing them parallel to each other and at right angles to the line joining their centres, and twisting them relatively to each other so that the projection of their corners on a parallel plane forms a regular octagon.

CONFIGURATION WHEN THE NUMBER OF ELECTRONS IS GREATER THAN EIGHT.

The following considerations show, however, that there must come a stage when it will no longer be possible to have all the electrons at the corners of a regular polyhedron.

To keep the electrons in stable equilibrium in spite of their mutual repulsion requires a finite positive charge and the greater the number of electrons and therefore the smaller the angular distance between an electron and its nearest neighbour, the greater the positive charge must be.

In Table I, I give the results of a calculation of the positive charge E required to keep n electrons in stable equilibrium.

The first line refers to the two-dimensional problem, when the electrons are arranged at equal intervals round the circumference of a circle with a positive charge at the centre; the second line refers to the three-dimensional problem when the electrons are at the corners of a polyhedron.

These numbers are for a law of force between the positive charge and the electron represented by $\frac{Ee}{r^2}\left(1-\frac{c}{r}\right)$. If the part of the force which does not vary inversely as the square of the distance varies inversely as some higher power than the cube, then the number of electrons which a given positive charge can keep in stable equilibrium will be increased.

TABLE I.

Two-dimensional problem.

$n=1$	2	3	4	5	6	7	10	12	14	16	8
$E/e>0$	.75	1.58	3.10	4.76	7.32	14.2	24.48	38.9	58	83	115

Three-dimensional problem.

$n=1$	2	3	4	6	8	12	20
$E/e>0$	.75	1.58	2.44	4.8	7.6	13	30

Confining ourselves for the moment to the case when the force is represented by $F=\frac{Ee}{r^2}\left(1-\frac{c}{r}\right)$, we see from the second table that when the number of electrons is not greater than eight, the electrons can be kept in equilibrium by a positive charge equal to the sum of the negative charges on the electrons, which is the greatest positive charge which can occur in a neutral atom. So that when the number of electrons is not greater than eight, a neutral atom can have these electrons arranged symmetrically at the same distance from the centre at the corners of a regular polyhedron. When, however, the number exceeds eight this is no longer possible. For we see from the table that to keep, say, nine electrons in stable equilibrium would require a positive charge more than $9e$, where e is the charge on an electron, but in a neutral molecule $9e$ is the maximum positive charge available when there are nine electrons in the atom. Thus the regular progression in the arrangement breaks down when the electrons amount to eight and a new arrangement must come into force.

Let us suppose that there are nine electrons; then these nine cannot all be arranged at the same distance from the centre, for this arrangement would be unstable since a positive charge of nine is insufficient to keep nine electrons in stable equilibrium. The charge $9e$ could, however, keep eight electrons in stable equilibrium at the same distance from the centre, leaving one to go outside. The distance of the eight electrons from the central charge would be $1.38\ c_9$, that of the single electron would be $9\ c_9$. So that the single electron would be a long way out from the centre of the atom.

If there are ten electrons, these can be arranged so that eight form a layer round the centre and two go outside, the distance of the eight from the centre would be $1.33\ c_{10}$, that of the two outlying ones would be $5.7\ c_{10}$.

Eleven electrons can be arranged with an inner layer of eight and an outer one of three, the distance of the inner one from the centre would be $1.3\ c_{11}$, that of the outer one $4.625\ c_{11}$.

Twelve electrons might be arranged with an inner layer of eight, radius $1.26\ c_{12}$ and an outer layer of four, radius $3.9\ c_{12}$.

Thirteen electrons, with an inner layer of eight, radius $1.227\ c_{13}$ and an outer layer of five, mean radius $3.52\ c_{13}$.

Fourteen electrons, with an inner layer of eight, radius $1.22\ c_{14}$; and an outer layer of six, radius $3.22\ c_{14}$.

Fifteen electrons, with an inner layer of eight, radius $1.2\ c_{15}$; an outer layer of seven, mean radius $3.1\ c_{15}$.

Sixteen electrons, with an inner layer of eight, radius $1.18\ c_{16}$; an outer layer of eight, radius $2.9\ c_{16}$.

We have now got eight electrons on the outer layer and there is not accommodation for any more; for since the atom is neutral the excess of positive over negative electricity in the system consisting of the central charge and the inner layer is equal to the charge on the electrons in the outer layer, thus if there were nine electrons in the outer layer there would be only an effective positive charge of nine to keep them in equilibrium. We can, however, get a system which will be in stable equilibrium if the electrons proceed to form a third shell; thus, if there are seventeen electrons, we could have an inner shell of eight, then another shell of eight and then an electron a long way outside. If we had eighteen electrons we should get two shells of eight and two electrons out-

side, and so on, until with twenty-four electrons we shall have filled up the third shell and have to begin again.

Let us now arrange the lighter elements in the order of the number of electrons they contain, and place underneath the symbol for the element the number of electrons in the outer layer of the atom. The number of free electrons in the atom has been taken as two less than the atomic number of the element, since two electrons always seem to cluster round the centre core and form a system by themselves.

TABLE II.

	Li	Be	Bo	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	A	K
Number of free electrons in the atom . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Number of electrons in the outer layer .	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1

THE PERIODIC LAW.

Thus, if we arrange the elements in the order of the number of electrons in the atom, which we have seen is the same as the order of the atomic weights, there will be a periodicity in the number of electrons in the outer layer. It will increase from one to eight, then drop again to one; increase again to eight, drop to one, and so on. Thus, as far as properties depending upon the outer layer are concerned, the elements will show a periodicity in their properties similar to that expressed by Mendeleef's periodic law in chemistry.

We shall show later on that the valency is a property depending on the number of electrons in the outer layer, the electropositive valency being proportional to that number, so that this type of atom would explain the periodic law.

VARIATION OF THE NUMBER OF ELEMENTS IN A PERIOD.

We have supposed that when the positive charge and therefore the number of electrons in the atom is increased by unity, the additional electron goes to the outer layer. This need not, however, necessarily be the case. When the positive charge is in-

creased, the number of electrons which it can hold in stable equilibrium on a spherical layer with its centre at the atom increases also; thus a large positive charge at the centre could hold more than eight electrons in the inner layer, and so the additional electron might, instead of going to the outside, find accommodation on one of the inner layers. Thus, since the valency depends on the number of electrons in the outer layer, if the additional electron was trapped in an inner layer, two consecutive elements, though they would have different atomic weights, would have the same valency. When there are a large number of electrons in the atom arranged in many layers it may require the addition of several electrons to the atom before there is any increase in the number in the outer layer and thus there might be a considerable number of adjacent elements with different atomic weights but with very similar chemical properties. There are groups of elements such as the iron, nickel and cobalt group, the rhodium group, the crowd of elements known as the rare earths, and the platinum group which fulfil this condition.

ALLOTROPIC FORMS.

There is in general more than one way in which the electrons can be arranged in stable equilibrium and though one particular arrangement may have the absolute minimum potential energy, yet calculation shows that in some cases the difference in potential energy between this configuration and some other one is exceedingly small and changes in the surroundings change the balance in favour of one or the other. If these configurations have different numbers of electrons in the outer layer, then they would correspond to forms with different valencies, and thus we may look in this direction for an explanation of the variable valencies shown by some elements. We shall return to this point later on.

The following table, calculated by Miss Woodward, gives in the third column the potential energy corresponding to the various arrangements of the electrons in atoms containing from three to eight electrons. The second column contains the distances of the electrons from the centre of the atom. Thus the figures corresponding to the arrangement of seven electrons in a double triangular pyramid with two electrons outside on the axis of the pyramid, indicate that the electrons on the triangular base are at a distance 1.244 c from the centre; those at the vortex of the inner

TABLE III.

Potential Energy of Atoms with Three to Eight Electrons.

Arrangement of Electrons.	Distances of Electrons from Atom.	Potential Energy.
Eight electrons.		
(i) One layer—twisted cube	1.447 c	$-16.75\ e^2/c$
(ii) One layer—cube	1.446 c	$-15.28\ e^2/c$
(iii) Two layers—tetrahedra similarly orientated	1.105 c (4) 3.108 c (4)	$-14.77\ e^2/c$
(iv) Two layers—six electrons in inner, two in outer ring	1.282 c (4) 1.267 c (2) 4.80 c (2)	$-15.012\ e^2/c$
Seven electrons.		
(i) One layer	1.37 c (2) 1.439 c (5)	$-12.181\ e^2/c$
(ii) Two layers—five in inner, two in outer ring	1.244 c (3) 1.191 c (2) 4.316 c (2)	$-12.096\ e^2/c$
Six electrons.		
(i) One layer	1.385 c	$-9.40\ e^2/c$
(ii) Two layers—four in inner, two in outer ring	1.196 c (4) 3.55 c (2)	$-8.868\ e^2/c$
Five electrons.		
(i) One layer	1.342 c (3) 1.376 c (2)	$-6.806\ e^2/c$
(ii) Two layers—four in inner, one in outer ring	1.273 c (3) 1.134 c (1) 5.105 c (1)	$-6.667\ e^2/c$
Four electrons.		
(i) One layer—corners of square	1.298 c	$-4.748\ e^2/c$
Three electrons.		
(i) One layer—equilateral triangle	1.238 c	$-2.934\ e^2/c$
(ii) Electrons on a straight line through atom	1.087 c 1.035 c 3.577 c	$-2.787\ e^2/c$

pyramid at the distance 1.191 c while the outer electrons are at a distance 4.316 c.

A simple example of the small difference in the potential energy between different configurations is afforded by an atom containing five electrons. We have described one such configuration when the five electrons were approximately at the same distance from the centre. There is, however, as we see from the table, another arrangement where four electrons are at the corners of a regular tetrahedron with its centre at the positive charge, while the fifth electron is a long way outside the tetrahedron. The mean distance of the electrons on the tetrahedron from the centre is approximately 1.22 c_5; where c_5 is the value of c for the fifth electron atom, while that of the outside electron is approximately 5 c_5, *i.e.*, more than four times greater. The potential energy of the second configuration is only about two per cent. greater than the first, thus there would be no great tendency for the second configuration to pass back to the other. The properties of the two configurations would, however, be quite different, in the second configuration we have a single electron far away from the others, this, as we have seen, is also the case with the alkali metals, in this configuration the five electron atom might be expected to show some of the properties of a monovalent element, in the other it would be pentavalent.

ACTIVE NITROGEN.

As nitrogen has an atom with five disposable electrons, it seems possible that the active form of nitrogen discovered by the present Lord Rayleigh may have this configuration. This active form is produced by passing an electric discharge through nitrogen and it is clear that if an atom were first ionised by the detachment of an electron the conditions would be favourable for the production of the configuration under consideration. For when the first electron is detached the remaining four will naturally arrange themselves in a tetrahedron round the centre, thus the nucleus of the configuration is already there and an additional electron at some distance from the centre would be more likely to take up a position outside than to force itself into the tetrahedron. As the second form has, like the alkali metals, a single electron at a great distance from the centre, we should expect that like them it would be attacked vigorously by halogens, and that as the outlying elec-

tron would require little work to detach it, this form of nitrogen would be easily ionised; both these properties are characteristic of Lord Rayleigh's active nitrogen.

We see that besides the two forms for the fifth electron atom there are forms for the sixth and seventh electron atoms which differ little in their potential energy in which two electrons are separated from the rest (*e.g.*, oxygen and fluorine). These would tend to be formed if the atoms were ionised so as to lose two electrons and then regain these electrons. As the number of atoms which lose two electrons when the electric discharge passes through a gas is small compared with the number which only lose one, we should not expect these modifications of oxygen and fluorine to be produced so freely as those of nitrogen.

EXPERIMENTAL EVIDENCE AS TO THE CONFIGURATION OF ELECTRONS IN THE ATOM.

We may hope when our sources of Röntgen radiation are more powerful to be able to obtain evidence of this by observing the interference effects produced when Röntgen rays pass through large numbers of neutral atoms. If the orientation of these atoms is a random one we can easily show that the interference of the rays scattered by the electrons will give rise to a series of rings. There will be a separate ring for every different distance between pairs of electrons in the atom. Thus if there were only two electrons there would only be one ring whose radius is proportional to the distance between the two electrons; again in an equilateral triangle there would only be one ring, for the distance between any two electrons is equal to a side of the triangle. If four electrons were at the corners of a regular tetrahedron there would again be only one ring for the distance between any two electrons is equal to a side of the tetrahedron. If, however, the four electrons were at the corners of a square there would be two rings, the radius of one being proportional to a side of the square, that of the other to its diagonal. Arrangement at the corners of a regular octahedron would also give two rings, the radius of one being proportional to the side of the octahedron, the other to the distance between two opposite corners. A cubical arrangement of electrons would, however, give three rings, the radius of one proportional to a side of the cube, that of the second to a diagonal

of a face and that of the third to the diagonal of the cube. Evidence of this kind is not, however, available at present.

As we shall see later on, the coefficient of diamagnetism gives on Langevin's theory of diamagnetism, the moment of inertia of the electrons about a line through the centre of the atom, this can be made to yield a certain amount of information about the disposition of the electrons, especially if we know from other sources the distance of the outer layer of electrons from the centre of the atom.

EVIDENCE AFFORDED BY POSITIVE RAYS.

More definite information can be got from evidence afforded by the positive rays. Let us first take the case of positively charged atoms. Their positive charge is due to their having lost electrons from the outer layer, now on this theory there is only one electron in the outer layer of the atom of hydrogen and in those of the alkali metals, so that these atoms should not be able to lose more than one electron and therefore should be unable to gain more than one unit of positive charge.

It is remarkable that these are the only atoms which in the positive ray spectra have not been observed with more than one positive charge. On the other hand, other light atoms have more than one electron and thus gain double or treble positive charges.

All such atoms when detected in the positive ray spectrum have been observed with double positive charges and in some cases such as carbon, nitrogen, oxygen with three or four, while as many as seven positive charges have been found in the atom of mercury.

Further confirmation of the views we have been discussing about the relation between the number of electrons and the property of the atom is afforded by the study of the occurrence of negatively electrified atoms in a gas through which an electric discharge is passing. By the method of the positive rays we are able to detect negatively as well as positively electrified atoms, and we find in this way that some atoms readily acquire a negative charge while others never do so. On the view we are considering, eight is the maximum number of electrons which can exist in the outer layer; as the atom of neon already possesses this number it cannot accommodate another electron and so cannot receive a negative charge. On the other hand the atom with a smaller

number of electrons in the outer layer has, as a reference to Table II shows, a superfluity of stability and can therefore accommodate another electron and thus acquire a negative charge. The superfluidity of stability is not, however, great enough for them to accommodate two electrons so that we should not expect to find any atoms with a double negative charge.

In the experiments with positive rays the atom of neon which has eight electrons in the outer layer has never been observed with a negative charge, while negative charges are common on atoms of hydrogen, chlorine, carbon and oxygen. No atoms have been observed carrying two negative charges.

It is remarkable that though carbon and oxygen, the neighbours on either side of nitrogen, readily acquire negative charges, nitrogen itself is very rarely observed with a negative charge. It was thought for a long time that the nitrogen atom never carried a negative charge, recently, however, I have observed in more intense discharges a faint line on the positive ray photograph corresponding to the negatively charged nitrogen atom, it is, however, very feeble in comparison with the adjacent lines due to negatively charged carbon and oxygen, respectively. A calculation of the work required to remove the additional electron from a negatively charged nitrogen atom shows that it is very small in comparison with that required to remove the additional electrons from negatively charged atoms of carbon or oxygen, so that a negatively charged nitrogen atom would easily lose its charge and so be difficult to detect.

Again the only negatively electrified atoms we can observe by the positive ray method are those which have previously been positively charged, *i.e.*, those which at one time have lost an electron. If such atoms, when they regain electrons, are in the condition we have ascribed to "active nitrogen" the electrons they regain will be far out from the centre of the atom and so would be very easily detached. Thus very few of those atoms could be expected to retain the electrons necessary to give them a negative charge.

There are some other interesting results which follow at once from the view we have taken of the constitution of the atom. The first we shall consider is the change in the chemical properties produced by electrifying the atom. Let us take the oxygen atom as an example, it has six electrons in the outer layer, and we

may anticipate the results to be given in the next chapter by saying that its valency is determined by the number of electrons in this layer. When the oxygen atom is positively electrified it has lost one or more electrons. If it is electrified so that it carries one unit of positive charge, the unit of charge being that carried by an electron, it must have lost one electron, so that the atom will only have five electrons in the outer layer, the same number as there are in a neutral atom of nitrogen. Thus, if the valency depends on the number of electrons in the outer layer, the valency of oxygen carrying a unit charge of electricity ought to be the same as that of a neutral atom of nitrogen, *i.e.*, it ought to form the the compound OH_3, a compound having the molecular weight 19. This is confirmed by observation with the positive rays, when hydrogen and oxygen are present in the tube, a line corresponding to this molecular weight is frequently observed. Again, if the oxygen atom carries a double positive charge, and observations on the positive rays show that oxygen atoms with this charge are frequent when the electric discharge passes through gases, the atom must have lost two electrons and will be left with only four in the outer layer, the same number as in the outer layer of a neutral atom of carbon; hence the doubly charged oxygen atom ought to have the same valency as neutral carbon, and thus form the compound $(OH_4)++$. This compound would carry a double charge and the ratio of m/e would be 10. I have found[1] in the positive ray, spectrum lines having this value of e/m when both oxygen and hydrogen were in the discharge tube.

Again the atoms of the inert gases which have eight electrons in the outer layer, would, if they acquired one unit of positive charge, have lost an electron and would only contain seven electrons in the outer layer. This is the number in the outer layer of a neutral halogen atom. The positively electrified atoms of the inert gases could thus like the neutral atoms of the halogens combine with one atom of hydrogen and thus the compound NeH would be possible if it carried a unit charge of positive electricity.

The molecular weight of this would be 21 and a line corresponding to a carrier with this molecular weight has been observed by Aston. The neon atom can, as observations on the positive rays show, lose two electrons, in this state it could combine with two

[1] *Proc. Roy. Soc.*, 101, p. 290.

atoms of hydrogen, or one of oxygen, the first of these molecules would have the value $m/e = 11$, and the second $m/e = 18$; the first could not be distinguished from the isotope of neon atomic weight 22 with a double charge, and the line due to the second would be identical with that due to water, so that the positive rays could not afford convincing evidence of the existence of these compounds. If we turn to negatively electrified atoms, a negative electrified chlorine atom would have eight electrons in the outer layer, it would resemble the neutral atom of an inert gas and so would not be able to enter into chemical combination. It would seem as if it ought not to be very difficult to determine this point by direct experiment.

The negatively electrified chlorine atom has the same number of electrons as a neutral atom of argon, both having eight in the outer layer. It might therefore be expected to resemble argon not merely in its chemical properties, but also in the nature of its spectrum. The spectra would not be identical, for the positive charge binding the electrons together would be greater for argon than for chlorine. The similarity in the arrangement of the electrons might be expected to lead to similarities in the spectra of negatively electrified chlorine atoms and neutral argon atoms. Again, a positively electrified potassium atom has lost an electron and so would contain the same number of electrons as a negatively electrified chlorine atom or a neutral argon one. Thus we should expect the spectrum of positively electrified potassium atoms to show similarities both with that of negatively electrified chlorine atoms and with neutral argon atoms. Professor Zeeman and Mr. Dik[2] have compared the red spectrum of argon, which is the one due to the neutral atom, with the spectrum due to positively electrified potassium atom and have found some exceedingly interesting points of resemblance. It is easier to observe the spectra due to positively electrified atoms than those due to negatively electrified ones, for in the latter case we should have to observe the spectrum they give out on receiving the negative charge, any attempt to stimulate them to luminescence afterwards would probably result in their destruction.

Similarly positively electrified oxygen atoms might be expected to give spectra resembling those of neutral nitrogen atoms

[2] *Proc. Amsterdam Akademie*, 25, pt. 3 and 4.

and positively electrified nitrogen atoms show similarities with neutral carbon atoms.

THE SIZE OF ATOMS.

By the radius of an atom we mean the distance of the electron in the outer layer from the centre of the atom. Let E be the central positive charge and

$$\frac{Ee}{r^2} - \frac{e^2C}{r^3} \tag{4}$$

the attraction between this charge and an electron at a distance r, e is the charge on the electron and $eC = cE$ where c is the quantity introduced in the expression for the same force (formula (1)), c is the distance at which the force between the positive charge and the electron changes from attraction to repulsion.

Then for the equilibrium of an electron on the outer layer we have

$$\frac{Ee}{r^2} - \frac{Ce^2}{r^3} = \frac{S_n}{4r^2}e^2 \tag{5}$$

where $S_n = \sum \frac{1}{\sin\theta}$, 2θ being the angle subtended at the centre of the atom by a pair of electrons and $\sum \frac{1}{\sin\theta}$ means that the sum of the values of $1/\sin\theta$ for each pair of electrons is to be taken. We get from this equation

$$r = \frac{C}{\frac{E}{e} - \frac{S_n}{4}} \tag{6}$$

The values of r for the lighter elements are given in the third column of Table IV. The fourth column is the value of r on the assumption that C is a linear function of the atomic weight, given by the equation $C = aN + b$, where N is the atomic weight and a and b constants.

Thus, taking the elements from lithium to neon, we see that the radius of the outer layer is greatest for the light elements and diminishes rapidly at first and then very slowly to the end of the period. When we pass from neon, the last element in this period, to sodium, the first in the next, there is a large increase in the radius. The sodium atom will have a larger radius than the lithium one, the ratio of the two will depend on the ratio of a to b, if a were zero the radii would be equal.

The increase in the radius which occurs at sodium is followed by a continually diminishing radius until we reach argon; when we pass to potassium, the first element in the next period, there is again an increase. The radii of atoms in the same group like lithium, sodium, potassium, or fluorine, bromine and iodine increase with the atomic weight of the element.

The relation between the radius of the atom and the atomic weight is such that the minima radii occur at the ends of the periods and, as in Lothar Meyer's well-known graph, which has been reproduced in almost every text-book of chemistry, not

TABLE IV.

Element.	N	E/e	S_n	r	
Hydrogen	1	1	0	C_H	$a + b$
Lithium	7	1	0	C_{Li}	$7a + b$
Beryllium	9	2	1	$4C_{Be}/7$	$5.14a + .57b$
Boron	11	3	2.3	$4C_{Bo}/9.7$	$4.52a + .412b$
Carbon	12	4	3.66	$4C_C/12.3$	$3.88a + .322b$
Nitrogen	14	5	5.2	$4C_N/14.8$	$3.78a + .270b$
Oxygen	16	6	6.68	$4C_O/17.3$	$3.69a + .23b$
Fluorine	19	7	8.08	$4C_F/19.9$	$3.8a + .21b$
Neon	20	8	10.1	$4C_{Ne}/21.9$	$3.63a + .182$
Sodium	23	1	0	C_{Na}	$23a + b$

at the middle. Recent experiments have shown, however, that this graph does not accurately represent the relation. Gervaise le Bas,[3] says,

1. "There is a periodic relation between the atomic volume and the atomic weight of the elements."

2. There is a tendency for the atomic volume to diminish in each series as the atoms increase in weight, the smallest occurs in group 7.

3. There is a general increase in the atomic volumes of each group from series one onwards, that is in the direction of increasing atomic weight.

This is in entire agreement with the results we have just found. The same thing is beautifully shown by the experiments

[3] "Molecular Volumes of Liquid Chemical Compounds," p. 237.

of W. L. Bragg[4] which give a curve (Fig. 1) for the atomic radii which in the period from lithium to neon agrees numerically very well with those deduced from the table (IV) given above, especially if b is small compared with a. The formula we have given would, unless a were very small compared with b, make the increase in atomic volume from lithium to sodium too great. According to Bragg the value of the sodium atom is only about 1.2 times that of the lithium one. While if the formula could be stretched from one period to another the increase would be much greater unless a were very small compared with b. We shall see later on that the law of the inverse cube only holds within a limited range of r and that beyond a certain distance the force seems to vary as the simple law of the inverse square. An effect of this kind would prevent any large increase in the radius of the atom as we passed from one period to another, and we should expect to find, as is the case, that the agreement between theory and experiment is most marked for the lighter and smaller atom.

IONISING POTENTIAL.

Another quantity which has been the subject of a great many experiments is what is known as the ionising potential. This is the work required to detach an electron from the atom, expressed as the fall of the charge on an electron through this potential. We may remark that the work required to detach the electron must depend upon the way in which it is done, so that the ionising potential is not a perfectly definite quantity. Thus to take two extreme cases, we may suppose the electron removed so suddenly that the other electrons have no time to change their position before it is out of their range of action, or to take the other extreme we may remove it so slowly that the electrons are always in their position of equilibrium corresponding to the position of the electron which is being ejected. In the first case the work required to move the electron away from the central positive charge is $\frac{Ee}{r} - \frac{1}{2}\frac{Ce^2}{r^2}$, and the work done by the other electrons in ejecting it is $e^2/r_{12} + e^2/r_{13} + e^2/r_{14}$ . . . where r_{12}, r_{13}, r_{14} are the distances of the ejected electrons from the other electrons indicated by the suffixes 2, 3, 4. Now $r_{12} = 2r \sin \theta_{12}$ where $2\theta_{12}$ is the angle between the

[4] *Phil. Mag.*, **40**, p. 169, 1920.

radii from the centre to the first and second electrons, and r is the distance of an electron from the centre, hence

$$\frac{e^2}{r_{12}} + \frac{e^2}{r_{13}} + \cdots = \frac{1}{2r}\left(\frac{1}{\sin\vartheta_{12}} + \frac{1}{\sin\vartheta_{13}} + \frac{1}{\sin\vartheta_{14}}\cdots\right)$$
$$= \frac{1}{2r} S_n \tag{7}$$

The work required to remove the electron is thus

$$\frac{Ee}{r} - \frac{1}{2}\frac{Ce^2}{r^2} - \frac{1}{2r} S_n \tag{8}$$

but from the equation of equilibrium

$$\frac{Ee}{r^2} - \frac{e^2 C}{r^3} = \frac{e^2 S_n}{4r^2}; \tag{9}$$

hence if V is the ionising potential, Ve, since it is equal to the work required to remove the electron, is given by the equation

$$Ve = \frac{Ee}{2} - \frac{3}{8}\frac{e^2 S_n}{r}, \tag{10}$$

if n is the number of electrons $E = ne$ and

$$V = \frac{e^2}{2r}\left(1 - \frac{3}{4} S_n\right). \tag{11}$$

Next take the case when the electron is removed so slowly that the system of electrons is always in equilibrium. The work required is the difference between the potential energy of the atom in its original state when it contains n electrons and in its final state when it contains $(n-1)$ electrons, the value of the former is

$$\frac{1}{2}\frac{ne^2}{r}\left(n - \frac{S_n}{4}\right) \tag{12}$$

that of the latter

$$\frac{1}{2}\frac{(n-1)e^2}{r_1}\left(n - \frac{S_{n-1}}{4}\right) \tag{13}$$

where r_1 is the radius of the atom when one electron has been removed.

For the equilibrium of the electrons in this state we have

$$\frac{Ee}{r_1^2} - \frac{e^2 C}{r_1^3} = \frac{e^2 S_{n-1}}{4r_1^2} \tag{14}$$

from the equilibrium of the atom in its original state we have

$$\frac{Ee}{r^2} - \frac{e^2C}{r^3} = \frac{e^2S_n}{4r^2} \tag{15}$$

hence

$$\frac{1}{r_1} = \frac{1}{r}\frac{\left(1 - \frac{S_{n-1}}{4n}\right)}{1 - \frac{S_n}{4n}} \tag{16}$$

and the difference between the potential energies is

$$\frac{1}{2}\frac{e^2}{r}\left\{n\left(n - \frac{S_n}{4}\right) - (n-1)\frac{\left(n - \frac{S_{n-1}}{4}\right)}{n - \frac{S_n}{4}}\right\} \tag{17}$$

$$= V_2 e$$

if V_2 is the ionising potential for slow ionisation. In calculating these ionising potentials we have assumed that the law of force between the positive charge and the electron was expressed by $\frac{Ee}{r^2} - \frac{e^2C}{r^3}$ at all distances, there is evidence, however, that the repulsive term varying inversely as the cube of the distance has only a limited range of action and that beyond this range the force varies strictly as the inverse square of the distance. If we suppose that the range of the repulsive force is $\rho Ce/E$, then the work done in taking an electron from a distance r to an infinite distance will be

$$\int_r^\infty \frac{Ee}{r^2}\,dr - \int_r^{\rho Ce/E} \frac{e^2C}{r^3}\,dr$$

$$= \frac{Ee}{r} - \frac{1}{2}e^2\frac{C}{r^2} + \frac{1}{2}\frac{E^2}{\rho^2 C} \tag{18}$$

In calculating the ionising potential, we have neglected the last term and so have underestimated its value. Neglecting this correction, the ionising potentials for the elements whose outer layers contain 1, 2, 3, 4, 5, 6, 7, 8 electrons, respectively, are given in the following table. r_1 is the radius of the outer layer of the one electron atom, r_2 that of the two electron atom and so on. The third column gives the potential in volts when the values of r_1, and r_2, given by W. L. Bragg (*loc. cit.*), are substituted in column 2.

TABLE V.

Number of Electrons in Outer Layer.	Ionising Potential for Quick Ionisation.	
1	$\frac{1}{2}e^2/r_1$	4.8 Lithium
2	$.625\,e^2/r_2$	8.1 Beryllium
3	$.633\,e^2/r_3$	
4	$.63\ e^2/r_4$	11.8 Carbon
5	$.54\ e^2/r_5$	12 Nitrogen
6	$.52\ e^2/r_6$	12 Oxygen
7	$.5\ e^2/r_7$	10.5 Fluorine
8		

These values apply to the ionisation of the atom and not of the molecule. In experiments on the ionising potential it is the value for the molecule and not for the atom which is in general determined.

SPECIFIC INDUCTIVE CAPACITY.

Further information about the atom is afforded by the study of the specific inductive capacity of the gas. We shall proceed to find the value of the specific inductive capacity of atoms containing different numbers of electrons.

The case of the one electron atom is exceptional because such an atom in its undisturbed state has a finite electrical moment, it will therefore tend to set in an electric field and this will give rise to a term in the specific inductive capacity independent of the displacement of the electrons inside the atom by the electric field; this term will vary rapidly with the temperature.[5] In addition to this effect due to the setting of the atoms there will be an effect due to the displacement of the electrons relative to the central core under the action of the electric field; this effect will be present in atoms containing more than one electron. The effect due to setting is absent when the normal atom has no finite electrical moment.

TWO ELECTRON ATOM.

If a is the distance of either of the electrons from the centre of the normal atom, X the external electric force, then if this force is in the direction of the line joining the electrons, the displace-

[5] *Phil. Mag.*, **27**, p. 757.

ment δx of either of the electrons in the direction of the force is given by the equation

$$e\delta x = \frac{4}{5} a^3 X \tag{19}$$

This displacement of the electron relative to the positive charge endows the atom with an electric moment $2e\delta x$, and if N is the number of atoms per cubic centimetre, the electric moment per cubic centimetre is

$$N \frac{8}{5} a^3 X \tag{20}$$

hence if K_1 is the specific inductive capacity of these atoms

$$K_1 - 1 = 4\pi N \frac{8}{5} a^3 \tag{21}$$

If the electric force acts at right angles to the line joining the electrons, then

$$e\delta x = 4a^3 X \tag{22}$$

and K_2, the specific inductive capacity for atoms orientated this way, is given by the equation

$$K_2 - 1 = 4\pi N \times 8a^3 \tag{23}$$

If the atoms in the gas are uniformly orientated, the specific inductive capacity K of the assemblage will be given by the equation

$$K = \frac{K_1 + 2K_2}{3}$$

or

$$K - 1 = 4\pi N a^3 \times \frac{8 \times 11}{15}. \tag{24}$$

The value of the specific inductive capacities for gases whose atoms contain from two to eight electrons is given in Table VI, which has been calculated by Miss Woodward.

It will be noticed that if K is the specific inductive capacity of a gas in the atomic condition, K is equal to ga^3, where a is the distance of the outer electrons from the centre of the atom, g is a quantity depending on the number of electrons in the outer layer. For elements belonging to the same family the number of electrons in the outer layer and therefore g is constant, so that the ratio of specific inductive capacities of two members of one family should be the same as the ratio of the volumes of the atoms. Cuthbertson has pointed out that there are some remarkably simple relations between the refractivities and therefore

between the values of $K-1$, for consecutive elements in the same family. This is shown by Table VII given by Cuthbertson and Prideaux.[6]

Thus for these four families the ratio of the refractivity of an element in the first period to the corresponding element in the

TABLE VI.

Specific Inductive Capacity of Atoms with Two to Eight Electrons.

No. of Electrons	Arrangement.	K.	Mean value of K.
8	Cube	$1+4\pi r^3N.\,4'338$	$1+4\pi r^3N.\,4'338$
8	Twisted cube force perpendicular to sq. face	$1+4\pi r^3N.\,4'27$	
7	One layer force perpendicular to plane of pentagon	$1+4\pi Na^3.\,3'605$	$1+4\pi a^3N.\,4'29$
7	One layer force parallel to plane of pentagon	$1+4\pi Na^3.\,4'634$	
6	One layer	$1+4\pi Nr^3.\,4'269$	$1+4\pi r^3N.\,4'269$
5	One layer force perpendicular to plane of triangle	$1+4\pi a^3N.\,4'655$	$1+4\pi a^3N.\,4'236$
5	One layer force parallel to plane of triangle	$1+4\pi a^3N.\,4'027$	
4	Tetrahedron	$1+4\pi Nr^3.\,3'9$	$1+4\pi Nr^3.\,3'9$
3	Triangle force perpendicular to plane of triangle	$1+4\pi Nr^3.\,5'203$	$1+4\pi Nr^3.\,4'39$
3	Triangle force parallel to plane of triangle	$1+4\pi Nr^3.\,3'981$	
2	Force perpendicular to line of electrons	$1+4\pi Nr^3.\,8$	$1+4\pi Nr^3.\,5'87$
2	Force parallel to line of electrons	$1+4\pi Nr^3.\,1'6$	

second and third periods is the same for all the elements. We have seen that for members of the same family the ratio of the values of $K-1$ is equal to the ratio of the volumes of the elements. So from these experiments we arrive at the interesting deduction that, on passing from one period to the next, the volumes of all the atoms are increased in the same proportion.

[6] *Phil. Trans.*, A, 205, p. 319.

TABLE VII.

Element.	Refractivities.	Approximate Ratio.
Helium	72.0	½
Neon	137.4	1
Argon	56.8	4
Krypton	85.0	6
Xenon	137.8	10
Fluorine	195	1
Chlorine	768	4
Bromine	1125	6
Iodine	1920	8
Nitrogen	297	1
Phosphorus	1197	4
Oxygen	270	1
Sulphur	1101	4

Some confirmation of this is furnished by the determinations by W. L. Bragg [7] of the diameters of the atom of the various elements, these were made by measuring by the Röntgen-ray method the distance between the metal and the negative element in a series of salts. In these the atoms of the negative elements are probably negatively charged and are not in the state of neutral atoms. For the electronegative elements the diameters are as follows:

Å is 10^{-8} cm.

F = 1.35 Å	O = 1.30 Å	C = 1.54 Å
Cl = 2.10 Å	S = 2.05 Å	Si = 2.35 Å
Br = 2.38 Å	Se = 2.35 Å	
I = 2.8 Å		

For the ratio of the diameters, we have

Cl/F = 1.55	Br/F = 1.76	I/F = 2.07
S/O = 1.57	Se/O = 1.8	
Si/C = 1.53		

For these elements, which are all electronegative ones, there seems thus some evidence from direct measurements that the ratio of the diameters of the atoms of corresponding elements in two

[7] *Phil. Mag.*, 40, p. 169.

periods is constant. It does not, however, apply to the electropositive elements like the alkali metals. Thus, for example,

Na/Li = 1.185	K/Li = 1.38	Rb/Li = 1.5	
Mg/Be = 1.24	Ca/Be = 1.5	Sr/Be = 1.7	Ba/Be = 1.8

Thus the increase in the size of the atoms of corresponding metals in different periods is not nearly so large as in that of the atoms of corresponding electromagnetic elements.

(To be continued.)

An Insect Enemy of Lead-covered Cables.—Beetles that bore through lead cables but do not penetrate pure rubber have given much trouble in many parts of the United States. An important injury is that done to the lead sheathing of telephone cables in California. The beetles bore holes about one-tenth inch in diameter and moisture enters through these, causing short circuiting. One hole may put several hundred telephones out of use. The Bureau of Entomology has been making experiments in this matter which are summarized in a professional paper, Bulletin 1107, by R. D. Hartman, H. E. Burke and T. E. Snyder. The insect is able to penetrate any lead alloy so far used as sheathing and any poison or repellent, except that beef tallow will suffocate it and has been used with some success on the rings which suspend the cable since nearly all borrowing is done at this point. A new type of ring made of flattened steel wire, galvanized, is now being installed and it is believed that this will be an efficient method. In the meantime, the use of tallow is the most promising available. (*U. S. Department of Agriculture Service.*)

Some Experiments on the Impact of Hydraulic Jets. A. H. GIBSON and F. HEYWOOD. (*Phil. Mag.*, Jan., 1923.)—When a jet of water impinges on a hemispherical cup, the force exerted on the cup can readily be calculated, provided it be assumed that the liquid is deflected 180° on impact. But this theoretical force is never attained. The angle of deflection is not equal to two right angles and surface friction reduces the velocity of the discharge. Besides this there is often interference between the incoming and outgoing liquid. The actual force exerted is a certain fraction, k, of the calculated force. A series of experiments was made in which the ratio of the area of the cup to that of the jet varied from about two up to ten times as much. The value of the coefficient, k, rose rapidly as the ratio just defined was increased from 2 to about 3.8, where it attained its maximum value of from .8 to .9. With further increases of the ratio k slowly decreased. With a velocity of the jet of 20 ft. per sec. to get the greatest force on a cup the ratio of the area of this to that of the jet needs to be 20, while for 60 ft. per sec. it should be 11.5. G. F. S.

PERMALLOY, AN ALLOY OF REMARKABLE MAGNETIC PROPERTIES.*

BY

H. D. ARNOLD, Ph.D.,

Member of the Institute

and G. W. ELMEN, M.A.

Research Laboratories,
American Telephone and Telegraph Company and Western Electric Company, Inc.

SOME years ago it was discovered in this laboratory that certain nickel-iron alloys, when properly heat-treated, possess remarkable magnetic properties.[1] These properties are developed in alloys which contain more than 30 per cent. of nickel and which have the face-centered cubic arrangement characteristic of nickel crystals, rather than the body-centered structure characteristic of iron. The entire range above 30 per cent. nickel exhibits these properties to some degree and offers new possibilities to those interested in magnetic materials.[2] The most startling results, however, are obtained with alloys of approximately 80 per cent. nickel and 20 per cent. iron, whose permeabilities at small field strengths are many times greater than any hitherto known. For convenience we call these peculiarly magnetic alloys by the general name "permalloy," which serves at the same time to recall their characteristic capability of attaining high initial permeability. The development of permalloy has assured us a revolutionary change in submarine cable construction and operation, and promises equally important advances in other fields of usefulness. It

* Communicated by Brigadier General John J. Carty, Vice-president and Chief Engineer, American Telephone and Telegraph Company and Associate Editor of this JOURNAL.

[1] The present paper deals with the scientific aspects of these alloys. Some of their important commercial applications have been disclosed in patents, among which may be mentioned the following: Canada, No. 180,539, Nov. 20, 1917; Japan, No. 32,331, March 7, 1918; France, No. 533,432, Dec. 9, 1921; Great Britain, No. 188,688, Nov. 17, 1922.

[2] Permeabilities higher than that of iron have also recently been found at the lower end of this range by J. Würschmidt, *Phys. ZS.*, **23**, 499–500 (1922), and *ZS. f. Phys.*, **12**, 128–164 (1922); low hysteresis, coercivity, and remanence have been observed in the upper part of the range by T. D. Yensen, *J. Amer. Inst. Elect. Eng.*, 39, 396–405 (1920); K. Zschiesche, *ZS. f. Phys.*, **12**, 201–214 (1922).

also presents questions of great interest to the scientist and emphasizes again the meagreness of our fundamental information about ferromagnetism. The present paper is intended to give a general discussion of the preparation and testing of permalloy, with sufficient detail to indicate its unusual characteristics. Detailed statements of numerical results are reserved for publication in separate articles dealing with specific properties.[3]

In making permalloy we use the purest commercial nickel and Armco iron. Our samples for laboratory study are prepared by melting these metals in a silica crucible, using a Northrup high-frequency induction furnace. The particular furnace which we use will conveniently melt a charge of about six pounds. An analysis typical of the resulting billets is as follows:

Ni	78.23
Fe	21.35
C	.04
Si	.03
P	trace
S	.035
Mn	.22
Co	.37
Cu	.10

The presence of other elements than nickel and iron is of course to be expected after any practical method of preparation. To determine their effects, samples were prepared in which the usual impurities were present in various proportions. It was found that their presence does affect the permeability of the alloys and that carbon is especially harmful. Since, however, the variations produced by slight changes in heat-treatment are very large compared with those due to small quantities of impurities we have found it unnecessary for most purposes to require higher purity than that indicated in the analysis above given.

In our laboratory studies we have made it a practice to reduce the billets through the forms of rod and wire to tape 3.2 mm. wide and 0.15 mm. thick. Accordingly test samples are available in a variety of forms and conditions. Thin narrow tape is

[3] L. W. McKeehan, "The Crystal Structure of Iron-Nickel Alloys," *Phys. Rev.* (2), **21** (1923).

particularly adapted to use in experiments involving heat-treatment, since it possesses a high ratio of area to volume and is easy to manipulate. Fortunately the entire nickel-iron series can be mechanically worked if sufficient care is exercised and we have thus been able to use samples of the same size, shape, and mechanical condition in all measurements upon which we have based comparisons between alloys. This practice has also made possible strictly comparable micrographic studies throughout the series.

Permeability is the magnetic characteristic of permalloy in which we first became interested and we have used its numerical value as an index in establishing the effects of mechanical and thermal treatments. Most of the measurements have been made in a ring permeameter of special design. The ring sample is prepared by winding twenty or more turns of tape around a disc about three inches in diameter. The disc is then removed, leaving the material in the form of a spirally laminated ring with a rectangular cross-section approximately 3.2 mm. by 6 mm. A single massive copper conductor is linked with this ring, and constitutes also the secondary of a transformer whose primary winding forms one arm of an inductance bridge. From the bridge measurements and the dimensions of the ring the permeability of the latter may readily be computed. For most of the measurements 112-cycle alternating current has been employed, permitting the use of telephone receivers in adjusting the balance of the bridge. The ring is sufficiently well laminated so that no serious troubles are introduced at this frequency by eddy currents. This fact was verified by making a number of permeability determinations at alternating current frequencies both above and below that chosen for routine use, and also by comparing the results of ring permeameter tests with those of ballistic tests on specially wound ring samples. The bridge method is particularly well adapted to the measurement of permeability in very weak magnetic fields since amplifiers may readily be used to increase the delicacy of the bridge adjustment to almost any degree desired. As a matter of convenience we have usually included in our test program measurements with fields of 0.002, 0.003, and 0.010 gauss, and on the graph of permeability against magnetizing field strength the straight line through these points has been extended to field

strength zero. We have called the permeability read from the graph at this point the "initial permeability" of the sample.

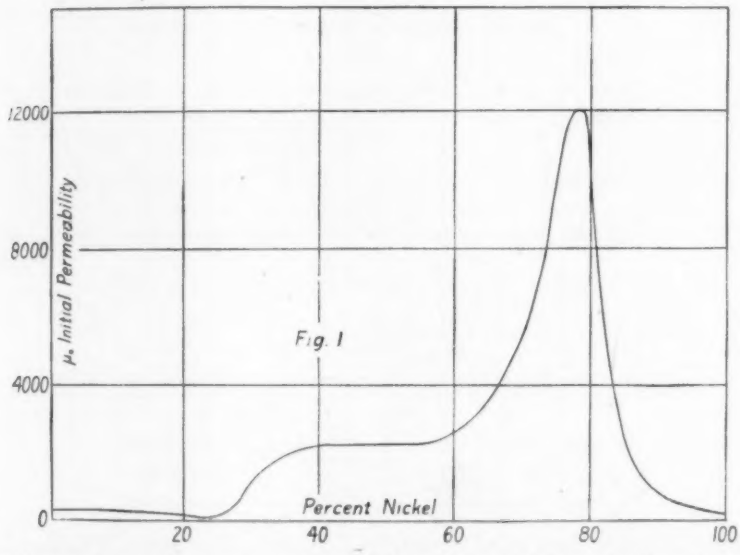
The form of permeameter used is especially adapted to making measurements quickly and with minimum handling of the sample, since it makes use of but a single magnetizing turn. The ring is laid on suitable insulating supports in an annular copper trough, and placing the copper cover on this trough completes the electrical circuit. In a modified instrument, the "hot permeameter," provided with a heating device, permeabilities may be measured from liquid air temperatures up to about 1000° C. without altering the position of the sample.

The heat-treatment of permalloy is of the utmost importance. To develop its maximum initial permeability it must be cooled not only through the proper temperature ranges, but also at the proper rates. It is obvious that only a small part of any sample can be given the most favorable treatment, since the interior portions of the sample cool at rates which are dependent upon the geometrical configuration and thermal properties of the material and are only indirectly under the control of the experimenter. For these reasons each shape and size of sample will have its own best heat-treatment and it is obviously difficult to establish the correct heat-treatment for a small element of volume, characteristic of permalloy as a material. By the use of thin tape, however, we secure fairly uniform treatment of the whole volume so long as the cooling is not too rapid, and fortunately the best cooling rate is not much different from the normal cooling rate of the tape in the open air. It has been found that temperature changes below 300° C. have very little effect upon the resultant properties of permalloy, but the rate of cooling from just above the magnetic transformation temperature down to about 300° C. is a controlling factor. By a long series of experiments a heat-treatment has been established which is especially well adapted to the permalloy test rings already described. They are first heated at about 900° C. for an hour and allowed to cool slowly, being protected from oxidation throughout these processes. They are then reheated to 600° C., quickly removed from the furnace and laid upon a copper plate which is at room temperature.

Not only does each size and shape of sample require its own

special heat-treatment, but samples differing only in composition also differ in their most suitable heat-treatments. In our investigation of the nickel-iron series we have not, however, attempted to determine the best heat-treatment for ring samples of each of the many alloys studied. By careful exploration we located the region about 80 per cent. nickel, 20 per cent. iron as the one promising the highest initial permeability and established the best heat-treatment for this composition. Keeping this treatment

FIG. 1.



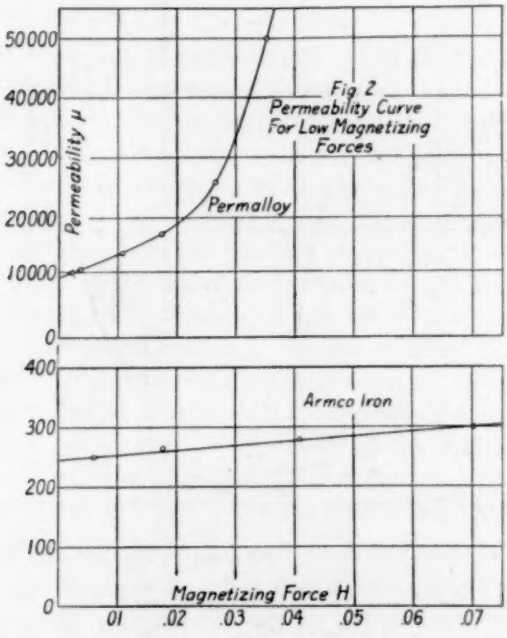
unchanged we then relocated the best composition, finding it to be at about 78.5 per cent. nickel and 21.5 per cent. iron. There is a maximum temperature in the equilibrium diagram for this binary at about 70 per cent. nickel,[4] and it was natural to suspect that the maximum in initial permeability which we had found at 78.5 nickel might be displaced to 70 nickel by proper treatment. The 70 per cent. nickel alloy was accordingly subjected to a great variety of heat-treatments, but no method was found capable of producing in it an initial permeability as high as that readily obtainable in the 78.5 per cent. nickel alloy.

Fig. 1 shows the general way in which initial permeability has

[4] Bureau of Standards Circular No. 58, April 4, 1916.

been found to vary throughout the nickel-iron series when the heat-treatment determined as best for the 80 per cent. nickel alloy is used. It is obvious from what has been said above that too much weight must not be given to the actual values recorded at any composition. Had the best heat-treatment been determined for each sample the curve might have been altered considerably in detail, particularly outside the permalloy range. We believe, however, that its general form is approximately correct. Alloys were

FIG. 2.

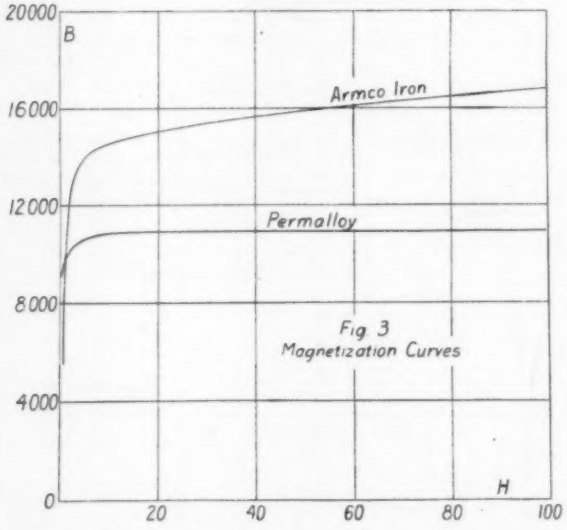


made at 5 per cent. steps throughout the range except in the vicinity of 80 per cent. nickel where a great number of slightly different compositions were investigated. The chemical analysis, rather than the intended composition, was used in every case, although the difference was never considerable.

The largest value of initial permeability for permalloy at room temperature which we have so far found in the ring permeameter is about 13,000, more than thirty times the corresponding value for the best soft iron. How extraordinary this is may be appre-

ciated by considering that this material, although it has a saturation value of magnetic intensity comparable with that of iron, approaches magnetic saturation in the earth's field. Unusual caution must therefore be exercised in measuring the properties of permalloy to protect the sample from the influence of stray magnetic fields. Fig. 2 shows, to different scales, the values of initial permeability in similar ring samples of permalloy and of

FIG. 3.



annealed Armco iron, and small portions of the corresponding μ-H curves from which these were obtained.

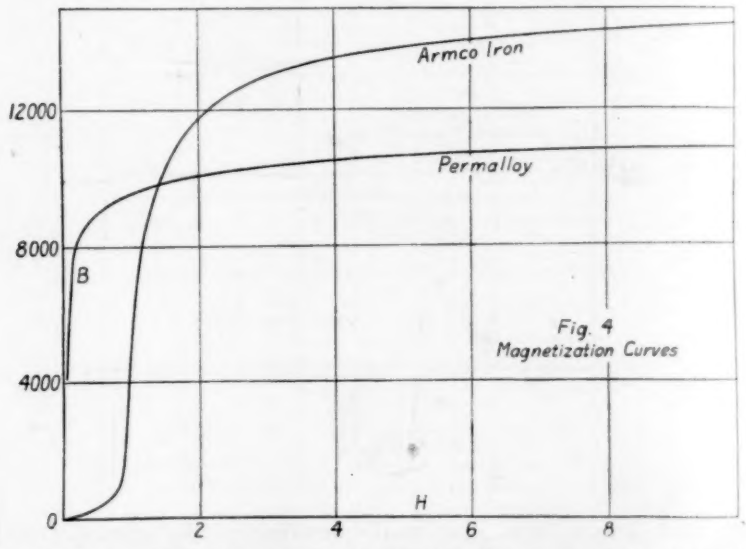
We have measured the magnetization of permalloy at saturation and find that it is not sensitive to heat-treatment. The saturation values of magnetization per gram-atom are known to vary almost linearly with composition throughout the nickel-iron series, from 222 for iron to 59 for nickel.[5] The value 84 which we have found for the 78.5 per cent. nickel alloy is therefore not abnormal.

The magnetic characteristics of heat-treated ring samples of the same alloy have also been determined through a wider range of field strengths by ballistic methods. Figs. 3, 4, and 5 show

[5] P. Weiss, *Farday Society Trans.*, **8**, 149–156 (1912).

B-H curves for such a sample of permalloy and for a sample of annealed Armco iron. From Fig. 5 is apparent the enormous susceptibility of the former material in the weak fields so important in communication engineering. Fig. 6 shows for the same two materials hysteresis loops carried to a maximum induction of 5000 gauss. The area of the permalloy loop is only one-sixteenth that of the loop for soft iron. Fig. 7 shows the μ-B curves for these materials. The maximum permeability here shown,

FIG. 4.



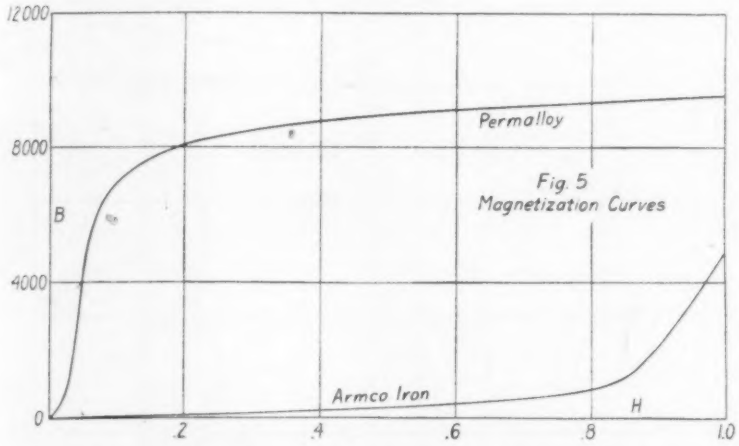
$\mu = 87{,}000$, which is not exceptionally high for permalloy, largely exceeds the highest values obtainable in silicon steel.[6]

Early in the investigations it was found that heat-treated permalloy is sensitive to strain, and the routine measurements were so conducted as to avoid this disturbing effect. Separate investigations of the effects of strain upon permeability and electrical conductivity in straight samples, and of the converse effects of magnetization upon dimensions and conductivity were also undertaken. While these studies are not yet complete it can be stated that all these effects are large in comparison with the corresponding effects in hitherto available magnetic materials. So long as

[6] T. D. Yensen, U. S. Patent No. 1,358,810, Nov. 16, 1920.

the elastic limit of the material is not exceeded the effects due to strain are reproducible and disappear when the strain is relieved. The effects of magnetization, however, show the expected hysteretic properties. As an example of the magnitude of the effects producible it may be stated that between its value in the unstrained condition and about one-tenth that value the initial permeability of a heat-treated strip of certain of these materials can, by the mere variation of strain, be adjusted to any value we may for the

FIG. 5.



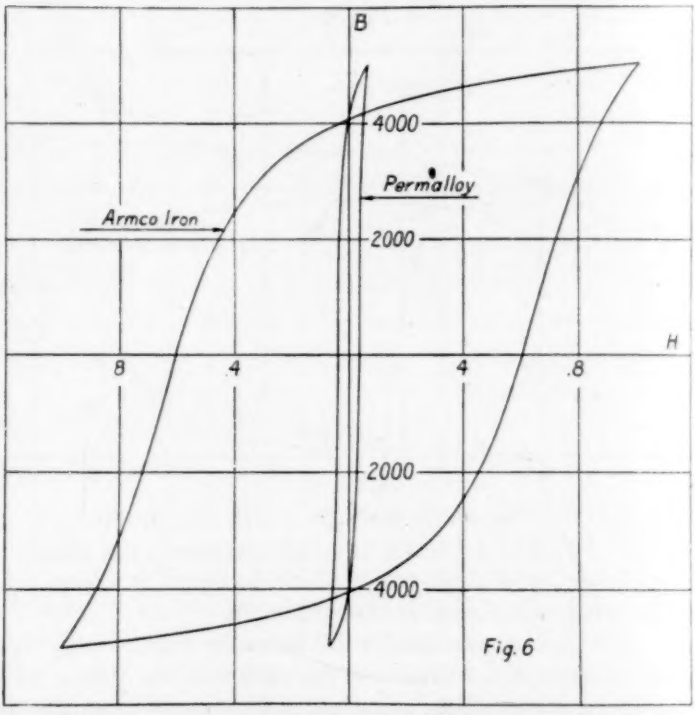
moment desire. The range through which the conductivity can similarly be adjusted by strain is much narrower, the maximum reduction being about 2 per cent.; which, however, is a large effect compared with that found in other metals.

The effect of magnetization in reducing conductivity is as much as 2 per cent. for fields of the order of one gauss. This makes it easy, for example, to measure the earth's magnetic field to within about 1 per cent. by finding the strength of the opposing field necessary to give a permalloy strip its maximum conductivity. It will be noted that the conductivity change which we have mentioned as attainable by magnetization is the same as that attainable by elastic strain. This is no mere coincidence, for we find that the maximum change due to either cause alone is not further increased by superposition of the other, although the effects of small tensions and magnetizing fields are additive.

This suggests, of course, that both causes ultimately produce the same change in the mechanism responsible for conduction.

Since the effect of tension upon permeability is in some of these cases so marked it seemed surprising that the only reported study[7] of the converse effect, that is, of magnetostriction, indicated a zero value within the permalloy range. It appeared advisable therefore to study the magnetostriction of the series of alloys

FIG. 6.



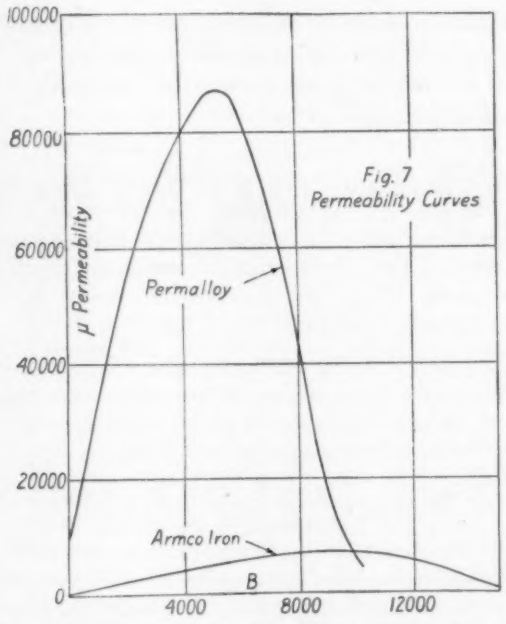
here available. Preliminary results indicate that under usual conditions of experiment, heat-treated 78.5 per cent. nickel alloy exhibits larger magnetostriction than does iron.

With the remarkable ferromagnetic behavior of permalloy in mind one naturally looks for analogous peculiarities in its other properties. As has been shown, however, the equilibrium diagram

[7] K. Honda and K. Kido, *Tohoku Univ. Sci. Rep.*, **9**, 221–232 (1920). It should be noted, however, that their alloys had received different treatments than ours.

does not point accurately to the composition exhibiting highest initial permeability. The conductivity curve is even less indicative of a peculiarity at this point, its minimum lying at about 35 per cent. nickel. The crystal structure is that of nickel and its type does not change until the nickel content is made less than 35 per cent. Even the mean spacing between adjacent atom-centres, and with it the density, varies continuously throughout the entire

FIG. 7.



range. Our experience in working these alloys also indicates that the series has no mechanical peculiarities at or near 80 per cent. nickel. Not only do these characteristics indicate no abnormality as the nickel content is increased beyond 70 per cent., but, what is more surprising, they are little affected by the heat treatments which so profoundly change the magnetic properties. So far as has been determined, therefore, it is only in connection with its magnetic properties that permalloy is unusual.

To the engineer the discovery of permalloy will mean the accomplishment of results heretofore believed impossible. For the scientist the principal interest in these materials may well lie

in the large response of their magnetic properties to simple external controls. Without alteration of composition these properties may be adjusted through extraordinary ranges by strain, by magnetization, or by heat-treatment. This allows a more definite study of the way in which these factors are related to magnetic properties than has been possible with materials hitherto available in which their effects are comparatively small and may be associated with complicated and irreversible changes in other properties. The behavior of permalloy demonstrates that ferromagnetism is associated with material structure in a different way than are the ordinary physical and chemical properties, and its extreme sensitiveness to control gives us a powerful method for use in magnetic investigations.

Method of Separating Arc from Spark Lines in Emission Spectra. W. WIEN. (*Ann. der Phys.*, No. 21, 1922.)—A few years ago the author found a way of observing luminous canal-rays even in the highest vacua. Upon this is based the method of distinguishing the two kinds of lines. A pencil of canal-rays enters a high vacuum through a narrow slit. The pressure in the vacuous space is kept low by a jacketing of solid CO_2 or liquid air. The pencil passes between the plates of a tiny condenser, the small size of which is demanded by the condition that the rays must be still emitting light when they make their exit from the space between its plates. The several spectral lines are photographed by a train of lenses and prisms.

When hydrogen is used the photographs are just the same no matter whether the condenser is charged to a potential difference of 4500 volts or not. The lines photographed were those of the Balmer series. It follows therefore that these lines are emitted by uncharged atoms. Quite different results are obtained with oxygen as the gas. Most of the lines were deflected toward the negative plate by the application of the electrical field. These were members of the spark spectrum of the gas. Two lines belonging to the arc spectrum were not deflected. The former lines are due to charged atoms, the latter to uncharged ones.

With nitrogen not only lines but bands were in evidence. Of the lines eight belonging to the spark spectrum were deflected, while two of the arc spectrum were not affected. Four bands are deflected. These are customarily designated " negative bands " and are due to positively charged molecules. A much larger number of bands fails to be deflected. There is a marked difference between the deflected lines and the deflected bands. After deflection the canal-rays producing the lines still emit considerable light while those producing the negative bands give out scarcely any light.

No mercury lines are deflected. G. F. S.

A METHOD OF TRANSMITTING THE TELEGRAPH ALPHABET APPLICABLE FOR RADIO, LAND LINES, AND SUBMARINE CABLES.*

BY

GEORGE O. SQUIER, K.C.M.G., D.S.M., Ph.D.

Major General, Chief Signal Officer of the Army.
Associate Editor, Honorary Member of the Institute.

DUE to the rapid expansion of the use of radio telephony and telegraphy, the problem of interference, both natural and artificial, is becoming each day more and more pressing for solution. The conservation of the ether lanes is suddenly rising to international importance. In addition, the daily growing uses of radio for the solution of auxiliary problems such as range finding, navigation, beacons, etc., further serve to complicate the problem, and furthermore, it is believed that we are on the threshold of another development, *viz.*, photo-broadcasting, which will require and demand still additional ether channels to serve the public of the near future. It may be said, therefore, that the fundamental problem for the radio engineer is to devise methods to utilize these limited channels to the greatest extent possible, and to bend his efforts to the extension of their limits, both high and low.

In the case of artificial disturbances the chief offender, from an engineering standpoint, is the radio telegraph practice as it is universally conducted at present. Radio telephony and music of all classes have a form of modulation which is scientifically more sound than that of telegraphy. It is impossible at present to tune out the high-power radio telegraph stations, especially when a receiving station is in close proximity. Such stations, as at present operated, produce a veritable eruption in the ether, creating disturbances over a wide range of frequencies, and these serve to interfere with any form of radio receiver yet devised. Who has not experienced this in the operation of his radio receiving set? Radio telegraphic transmission, therefore, demands new consideration and new study from a scientific standpoint.

About eighty years ago Morse invented the telegraph alphabet of dots and dashes, and the modification of it, known as the International Morse, is now the universal method of international

* Communicated by the Author.

radio telegraphy. This method is believed to be fundamentally unscientific, and the time has come to thoroughly consider a radical revision of the method of sending telegraphic messages. I do not here refer to an actual change at present in the Morse alphabet as regards the combinations of dots, dashes and spaces assigned to each letter, but I refer to the study of the correct method of sending these combinations in any circuit, whether radio, land lines, or submarine cables. The problem is the same in each of these three branches, but it is much more serious in radio for the reason of the necessary broadcasting properties thereof.

The rapid increase in the use of printing telegraphy makes it possible to further consider the telegraph alphabet from the standpoint of the number of the elements and the combinations thereof for each letter. This phase of the problem is now being studied by the Code Section of the Signal Corps.

In the Morse alphabet we find the principle of different time units for dots, dashes and spaces, as the basic idea of the system. In Standard Morse a dash is three times the length of time of a dot, and the spaces between letters and words are timed correspondingly.

These signals in International Morse are universally emitted into the ether from the transmitting antenna in the form of sudden interruptions in the antenna current, or sudden variations in this current. This method produces about the worst possible source of disturbances in the ether space for the reason, among others, that the disturbance has no regularity of any kind, and the speed of operating the sending key has a marked influence on the whole phenomena. Present practice is drifting away from the complete interruption of the antenna current which is the worst from an interference standpoint, but even the present methods of irregular and sudden variations of the current are still a long way from the possible scientific solution.

In 1915 [1] the writer was considering the general problem of improving the transmission system for submarine cables, and in connection therewith gave study to a new form of alphabet suitable to such a circuit. The system devised at that time may be

[1] "On an Unbroken Alternating Current for Cable Telegraphy," *Proc. Phys. Soc. of London*, 27, Part V, August 15, 1915. U. S. Patent No. 1,233,519. July 17, 1917.

described briefly as a continuous wave system: "c.w." *versus* the "spark" system of the present cable practice. A method was developed of sending an unbroken alternating current through the cable, and means provided for interpreting this alternating current into intelligible signals. This system abandoned the Morse principle of different lengths of time for the signals as being fundamentally inefficient, and adopted the plan that all individual signal units should occupy equal lengths of time, and have equal importance, whether they were dots, dashes or spaces. The signals were distinguished by varying the intensity of the individual sending elements, *i.e.*, a dot, dash or space occupied equal time lengths, but were of different intensities. The variation in intensity for signalling was effected at the transmitter at the zero phase of the resultant current flowing into the cable, so that, theoretically, at the moment of any operation upon the current there was no current to operate upon.

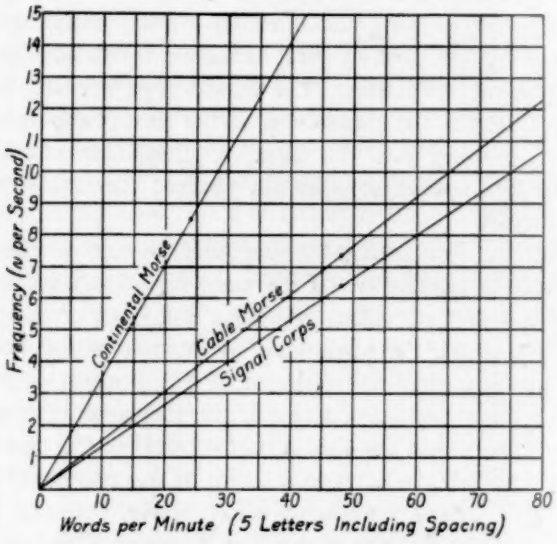
A point of fundamental importance in this method is that no two adjacent signals are of the same sign, since each semicycle is utilized to effect signalling, giving a dot, dash or space. Other things being equal, the variations in intensities for each of the three elemental signals are reduced to a minimum on the theory that the minimum possible change of the fundamental wave should be made. The reason for this is that an alternating current in the steady state, which amounts to a series of the present cable letters "a" or "n" strung together without space, can attain a speed in any form of telegraphy many times greater than any practical system. A sinusoidal wave is transmitted through any form of electrical circuit without distortion of any kind, and, in fact, is the only type of wave that is so transmitted.

A still more important point to be considered is the transmission of the largest volume of telegraphic business with a minimum number of signals, and from this angle the new form of alphabet has most striking advantages.

Fig. 1 exhibits graphically the relative speeds of the International Morse alphabet, the present cable alphabet, and the alphabet proposed here. It will be noted that by the employment of the alphabet proposed here we gain immediately over 150 per cent. in the speed of transmission of signals; the ratio of 8.5 to 3.2, as shown in Fig. 1, is 2.65.

Referring to the cable Morse alphabet, the ratio of 3.67 to 3.2 does not indicate the real advantages of the proposed alphabet. In the present cable Morse alphabet, although the signals occupy equal lengths of time, some of the letters are transmitted by adjacent signals of the same sign. In letters such as "s" or "h," for instance, three and four consecutive signals have the same sign. The additional principle of the Signal Corps alphabet that

FIG. 1.



Infra-audio frequencies.

Note: Based on operating experiences with traffic in plain English text. Average time units per letter as follows: Continental Morse, 8.5; Cable Morse, 3.67; Signal Corps, 3.2; Ratio of 8.5 to 3.2=2.65.

no two consecutive signals shall be of the same sign permits, for the first time, a continuous wave of one definite frequency being employed for the alphabet. This makes it possible to utilize, effectively, electrical and mechanical tuning, either or both.

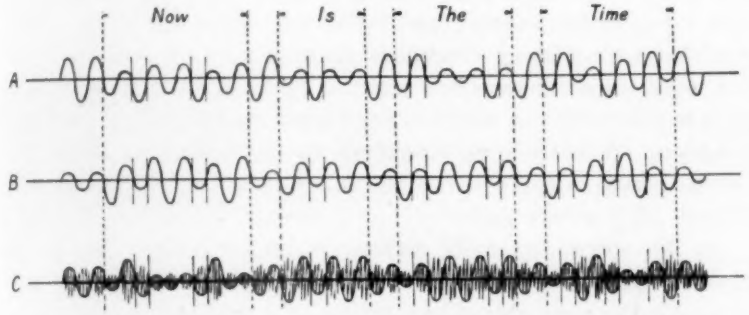
Fig. 2_B illustrates graphically this method of modulating a single frequency wave, and shows the words "Now is the time" as they would be transmitted by this method, in which we arbitrarily assign the largest amplitude for a dash, the next size amplitude for a dot, and the smallest for the spaces between.

Figs. 2_A and 2_C show two other combinations.

The particular combination 2_B has been tried out in actual practice on cables, and has been tested by the engineers of the British Post Office.

If we consider the present method of operating the large radio telegraph stations we find that the method of sending, whether automatic or by hand, has no relation to the phase of the current flowing in the antenna, with the result that in the ordinary transmission of a message the large current flowing in the antenna, sometimes as much as two or three hundred amperes, is suddenly

FIG. 2.



(*A*) Dot—smallest amplitude. Dash—medium amplitude. Space—largest amplitude.
(*B*) Space—smallest amplitude. Dot—medium amplitude. Dash—largest amplitude.
(*C*) Dash—smallest amplitude. Space—medium amplitude. Dot—largest amplitude.
There are three other possible permutations of amplitudes not shown here. Ratio of amplitudes of signalling units arbitrarily assumed as 1: 2: 3.

interrupted or changed in a perfectly haphazard manner. The transmitting key is closed or opened at any indefinite point of phase, with the result that in the same letter or message a large flow of current is interrupted or changed at all possible values from zero to a maximum, positive or negative.

It is well known that the sudden breaking or introduction of high impedances in an alternating current circuit produces transient phenomena which results in a whole group of harmonics being transmitted. Add to this the practical condition of performing this operation upon a current ranging all the way from zero to hundreds of amperes, and it is easily seen that the ether of space is bombarded with a mass of frequencies never twice alike even in the same letter. It is little wonder, therefore, that no method has yet been devised to prevent such a disturbance from interfering radically with the reception of radio signals. Entirely

apart, therefore, from a gain of over 150 per cent. in the transmission speed, from an interference standpoint the present method is about as bad as it could well be.

The other source of disturbances in radio is natural disturbances, generally designated as "static" or "atmospherics." Here again it is believed that the solution may be found in the method of sending proposed here, for the reason that the modulating frequencies employed are of a very low order, and it should be comparatively simple to devise instrumentalities which will enable us to differentiate between these low modulating frequencies and the higher frequencies of the "static" or any other natural disturbance. To emphasize my point, by an examination of Fig. 1 it is seen that a modulating frequency as low as 10 per second, which is a very high frequency for ocean cable practice, corresponds to 75 words a minute, which is far higher than any form of sound reception. A modulating frequency of 60 cycles per second, the normal power frequency, corresponds to a speed of 450 words a minute, of 5 letters each.

If this speed, for traffic reasons, is too great, it is only necessary to make the same perforations in the transmitting tape correspond to a suitable even multiple of a semicycle to reduce the speed to any desired value. For instance, by making each of the signalling units correspond to six complete cycles of current instead of one semicycle, the speed of signalling is reduced to 37½ words a minute, a commercial speed of signalling. In this method of using the alphabet, wave trains are employed as the signalling elements.

The ratio of the lowest frequencies employed in radio to the modulating frequencies here considered is of the order of thousands.

At present the radio engineer has utilized and made his own all of the audio-frequency range and at least several octaves of the radio-frequency range, and has devised apparatus for the amplification and rectification of both of these ranges, audio and radio. This plan proposes to enter the unused infra-audio range, which would not only add a most useful band of frequencies to those now used, but would give a band below the range of the human ear. If this band were employed for telegraphy, an additional advantage would be that it could not interfere with any radio

receiving. This method of eliminating interference would be most effective.

Finally, it is seen that by the method proposed here it is possible to modulate a single radio frequency by a number of modulating frequencies, and thus multiply the capacity of each radio frequency channel.

In 1921 the writer attended at Paris an international technical conference on outstanding radio problems, and for two months special delegates of the five great powers gave consideration to technical points connected with international radio telephony and telegraphy. Such matters as interference, logarithmic decrements, disposition and allocation of wave-lengths, radiation, etc., were considered. It is now proposed that the general subject of a suitable method for transmitting telegraphic signals either for radio, land lines or submarine cables be considered at the next international technical conference, with a view, if possible, of unifying all branches of telegraphy using the same system of modulation for the signals.

Office of the Chief Signal Officer,
War Department,
Washington, D.C.,
March 6, 1923.

A Problem in Viscosity: The Thickness of Liquid Films Formed on Solid Surfaces Under Dynamic Conditions. F. S. GOUCHER and H. WARD. (*Phil. Mag.*, Nov., 1922.)—"In many important industrial processes solid surfaces are coated with a layer of liquid by drawing them out of a bath of the liquid. The enamelling of wires or tubes is such a process, and so in all essentials is painting with a brush. We are aware of no theory or even complete experimental investigation directed to determine how the thickness of the liquid layer produced in such circumstances varies with the properties of the liquid, the solid surface, the velocity of drawing, and other possible factors. The experiments described in this paper show that the matter is surprisingly simple." Let us consider a very wide sheet of solid material being drawn with constant velocity vertically upward out of a liquid. Since observation shows that the thickness of the layer of liquid adhering is, at least under certain conditions, constant for considerable distances above the surface of the liquid, it follows that the motions of the layers of adhering liquid must be in vertical planes parallel to the solid. Deviation from vertical motion would cause a change in the thickness of the film. The solid is moving upward and drags with it at the same velocity the layer of

liquid adjacent to it. This layer viscously drags the layer next to it, but this does not move upward with the velocity of the solid owing to the force of gravity. As we give attention to layers farther and farther distant from the solid, we find them moving upward with less and less velocity. The surprising conclusion is reached that the outermost layer is neither rising nor sinking. Since the forces due to viscosity and to gravity are the only forces acting on the layers of liquid, and since they produce a steady state of flow, it follows that they just balance each other. After solving the appropriate differential equations this relation is derived, $t^2 = \frac{2v_0\eta}{\rho g}$, where this thickness of adhering liquid, v_0 is velocity of solid, ρ is density of liquid and η its coefficient of viscosity. No property of the material forming the solid appears in the formula.

A study of the coating of wax forming upon copper strips was made. The actual thickness of the layer was usually somewhat greater than the value calculated from the constants of the liquid wax. This is due to the fact that as soon as a layer of molten wax is drawn out of the main body of the liquid its temperature falls and in consequence of this the viscosity grows greater.

When tubes are used surface tension comes into play. On the outside of the tube the contraction of the surface of the liquid acts along with gravity to make the layer thinner, while inside of the tube these two forces are in antagonism. Hence the thickness of the layer within the tube is greater than that outside of it. G. F. S.

Franklin Bache.—DR. EDGAR F. SMITH has published a brochure on "Franklin Bache, Chemist," in his series of treatises on the history of chemistry in America. Doctor Bache, who was a great-grandson of Benjamin Franklin, was an early member of The Franklin Institute, having been elected to membership in 1827. He was professor of chemistry in the Jefferson Medical College and the Philadelphia College of Pharmacy, founded the United States Dispensatory, and prepared for publication the treatise of James Cutbush, entitled "A System of Pyrotechny," after the death of Cutbush. In 1841, Bache stressed the great importance of chemistry in its applications to medicine and pharmacy. J. S. H.

The Electrical Resistance of a Rotating Coil. A. P. CARMAN. (*Phys. Rev.*, April, 1922.)—Maxwell stated that "the electric current has a true momentum." A coil of "advance" wire, wound upon a disc, was rotated at 7000 r.p.m. about the axis of the disc, in order to see whether the rotation would throw the current away from the axis and into the outer parts of the coil. Such a redistribution of the current should manifest itself by an increase in the resistance of the coil. In spite of a peripheral speed of 10 km. per sec., an increase of resistance of merely one part in 100,000 was obtained. Even this may be attributed to other causes. G. F. S.

ELECTRIC FILTER CIRCUITS.*

BY

LOUIS COHEN, Ph.D.

Consulting Engineer, Signal Corps, U.S.A.

THE theory and operation of electric filter circuits, the invention of Dr. G. A. Campbell, has been discussed in several able papers by Doctor Campbell himself and others. A very clear exposition of the fundamental principles of electric filter circuits and the working out of many design formulas are given by Doctor Campbell in the two patents issued to him in 1917.[1]

In all the discussions of the subject, however, the problem is considered from the standpoint of an artificial line, and creates the impression that an electric filter circuit, which, as is well known, consists of a number of circuits connected together in various forms, involves a new principle and the theory of it is different from that applied to ordinary coupled circuits. It is true that when an electric filter circuit is made up of a large number of independent circuits it assumes the character of an artificial line, having certain characteristics governed by the arrangement of the inductance and capacity in each individual circuit. But is it justifiable to consider the problem from the standpoint of an artificial line when only a very limited number of circuits or sections is used, say two or three sections only, and if not, what are the limiting conditions, what is the minimum number of sections required for the system to acquire the characteristic properties of an electric filter, that is, to permit band frequency tuning? And if the number of sections is below the minimum number required, can we obtain band frequency tuning in any degree whatsoever? The answers to these questions are not obvious

* Communicated by Major General George O. Squier, Chief Signal Officer, U.S.A., and Associate Editor of this JOURNAL.

[1] See U. S. Patents Nos. 1,227,113 and 1,227,114 issued to Dr. G. A. Campbell, May 22, 1917.

"Physical Theory of Electric Wave Filter," by G. A. Campbell, *The Bell System Technical Journal*, November, 1922.

"Theory and Design of Uniform and Composite Electric Wave Filters," by Otto J. Zobel, *The Bell System Technical Journal*, January, 1923.

when the problem is considered from the viewpoint of an artificial line, and certainly it is not at all clear when the problem is treated in that light as to the extent of improvement in band tuning obtained as the number of sections used is gradually increased.

It is believed that the whole problem is much simplified and the interpretation of the physical principles governing the operation of the electric filter circuit is more easily understood in considering the problem from the standpoint of coupled circuits. After all, an electric filter is nothing more, of course, than a number of independent circuits joined together electrically. The connection between the individual circuits may be either direct or through any other type of coupling, and there does not seem to be any reason why the problem should not be considered from the standpoint of coupled circuits, and thus enable us to see clearly what may be expected in the matter of frequency tuning from a system of circuits of any number of sections whatsoever, say two, three, or more, and also obtain some information of the improvement or change in conditions as the number of circuits used is gradually increased. Strictly speaking, it is only when the number of sections used is infinitely large that the system may be considered as an artificial line, and this condition is only approximated when a finite number of sections is used. By considering the problem from the standpoint of coupled circuits, we should be able to see how closely we approximate the condition of an infinite number of sections when only a limited number of sections or independent circuits is used.

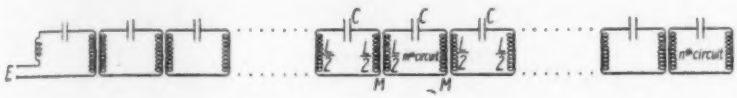
In what follows I have considered, first, a system of electromagnetically coupled circuits and have shown that strictly band tuning is obtained only when an infinite number of independent circuits is used, but that the condition of band tuning is closely approximated when a limited number of sections is employed. From the theory given here, curves could be easily plotted for any particular case, showing the deviation from the uniform band tuning for any limited number of circuits.

I also apply the same considerations to a system of direct connected circuits the usual arrangements employed in the design of electric filter circuits.

For a system of circuits consisting of n circuits coupled electromagnetically, as shown in Fig. 1, a sine e.m.f. $Ee^{j\omega t}$

impressed on first circuit, we have the following system of equations:

FIG. 1.



$$\left.\begin{aligned} &ZI_1 + Mj\omega I_2 = E\varepsilon^{j\omega t},\\ &ZI_2 + Mj\omega I_1 + Mj\omega I_3 = 0,\\ &\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\ &ZI_m + Mj\omega I_{m-1} + M\omega jI_{m+1} = 0,\\ &\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\ &ZI_n + Mj\omega I_{n-1} = 0 \qquad . \end{aligned}\right\} \tag{1}$$

Z is the impedance of each of the circuits and M is the mutual inductance between any two adjacent circuits. All the equations except the first and the last are satisfied by the following solution:

$$I_m = A\varepsilon^{m\gamma} + B\varepsilon^{-m\gamma}. \tag{2}$$

Substituting in (1) we have

$$Z(A\varepsilon^{m\gamma} + B\varepsilon^{-m\gamma}) + Mj\omega(A\varepsilon^{(m-1)\gamma} + B\varepsilon^{-(m-1)\gamma} + A\varepsilon^{(m+1)\gamma} + B\varepsilon^{-(m+1)\gamma}) = 0, \tag{3}$$

or

$$A\varepsilon^{m\gamma}\{Z + Mj\omega\varepsilon^{-\gamma} + Mj\omega\varepsilon^{\gamma}\} + B\varepsilon^{-m\gamma}\{Z + Mj\omega\varepsilon^{\gamma} + Mj\omega\varepsilon^{-\gamma}\} = 0, \tag{4}$$

and all the equations of (1) are satisfied by the above solution if we assign to γ such a value as to satisfy the relation

$$Z + Mj\omega(\varepsilon^{\gamma} + \varepsilon^{-\gamma}) = 0,$$

or

$$\varepsilon^{\gamma} + \varepsilon^{-\gamma} = -\frac{Z}{Mj\omega}. \tag{5}$$

The constants A and B of the solution given by (2) are determined from the first and last equations of (1). We have in this case

$$\left.\begin{aligned} &Z(A\varepsilon^{\gamma} + B\varepsilon^{-\gamma}) + Mj\omega(A\varepsilon^{2\gamma} + B\varepsilon^{-2\gamma}) = E\varepsilon^{j\omega t},\\ &Z(A\varepsilon^{n\gamma} + B\varepsilon^{-n\gamma}) + Mj\omega(A\varepsilon^{(n-1)\gamma} + B\varepsilon^{-(n-1)\gamma}) = 0. \end{aligned}\right\} \tag{6}$$

The values of A and B are readily determined from the above two equations as follows:

$$\left.\begin{aligned} A &= \frac{E\varepsilon^{j\omega t}\,\varepsilon^{-n\gamma}(Z + Mj\omega\varepsilon^{\gamma})}{\varepsilon^{-(n-1)\gamma}(Z + Mj\omega\varepsilon^{\gamma})^2 - \varepsilon^{-(n-1)\gamma}(Z + Mj\omega\varepsilon^{-\gamma})^2}, \\ B &= \frac{E\varepsilon^{j\omega t}\,\varepsilon^{n\gamma}(Z + Mj\omega\varepsilon^{-\gamma})}{\varepsilon^{-(n-1)\gamma}(Z + Mj\omega\varepsilon^{\gamma})^2 - \varepsilon^{-(n-1)\gamma}(Z + Mj\omega\varepsilon^{-\gamma})^2}. \end{aligned}\right\} \quad (7)$$

Taking into account the relation given by (5) the above reduce to

$$\left.\begin{aligned} A &= \frac{E\varepsilon^{j\omega t}\,\varepsilon^{-(n+1)\gamma}}{Mj\omega(\varepsilon^{(n+1)\gamma} - \varepsilon^{-(n+1)\gamma})}, \\ B &= \frac{E\varepsilon^{j\omega t}\,\varepsilon^{(n+1)\gamma}}{Mj\omega(\varepsilon^{(n+1)\gamma} - \varepsilon^{-(n+1)\gamma})}. \end{aligned}\right\} \quad (8)$$

Substituting these values in (2) we get the complete expression for the current in any circuit, say the mth circuit, as follows:

$$I_m = \frac{E\varepsilon^{j\omega t}\left\{\varepsilon^{(m-n-1)\gamma} - \varepsilon^{-(m-n-1)\gamma}\right\}}{Mj\omega\left\{\varepsilon^{(n+1)\gamma} - \varepsilon^{-(n+1)\gamma}\right\}}. \quad (9)$$

For the last circuit, $m = n$

$$I_n = \frac{-E\varepsilon^{j\omega t}\left\{\varepsilon^{\gamma} - \varepsilon^{-\gamma}\right\}}{Mj\omega\left\{\varepsilon^{(n+1)\gamma} - \varepsilon^{-(n+1)\gamma}\right\}}, \quad (10)$$

$$= \frac{-E\varepsilon^{j\omega t}\sinh\gamma}{Mj\omega\sinh(n+1)\gamma}.$$

Obviously the current is of maximum value when the value of γ is such as to give the denominator a minimum value. If we neglect the resistance, the denominator of equation (12) is the reactance of the system and is of zero value when adjusted for resonance condition.

For

$$\left.\begin{aligned} &\operatorname{Sinh}(n+1)\gamma = 0, \\ &(n+1)\gamma = js\pi,\ s = 0, 1, 2, 3, \cdots \\ &\gamma = \frac{js\pi}{n+1}. \end{aligned}\right\} \quad (11)$$

The function $\operatorname{Sinh}(n+1)\gamma$ is zero for all integer values of s from zero to infinity, but the zero value of s and the values above n are to be disregarded because for $s = 0$ the numerator in the expression for the current given by (10) also becomes zero, and the current therefore is not a maximum for $s = 0$; also for values

of $s > n$ we get a repetition of the values obtained from assigning to s the values from 1 to n, and nothing is contributed by using the values of $s > n$.

For two coupled circuits we have only two values of γ

$$\left.\begin{aligned}\gamma_1 &= j\frac{\pi}{3},\\ \gamma_2 &= j\frac{2\pi}{3}.\end{aligned}\right\} \tag{12}$$

For three coupled circuits there are three values of γ

$$\left.\begin{aligned}\gamma_1 &= j\frac{\pi}{4},\\ \gamma_2 &= j\frac{2\pi}{4},\\ \gamma_3 &= j\frac{3\pi}{4}.\end{aligned}\right\} \tag{13}$$

Similarly for n coupled circuits n values of γ.

The frequencies for which the system is in resonance are determined from the relation given by (5). Substituting the values of γ from (11) in (5) we get the following:

$$2\cos\frac{s\pi}{n-1} = -\frac{Z}{Mj\omega}. \tag{14}$$

If the reactance of each circuit is simply that of an inductance and capacity in series, $Z = Lj\omega + \frac{1}{Cj\omega}$, (14) takes the form

$$2\cos\frac{s\pi}{1-n} = -\frac{L}{M}\left(1 - \frac{1}{LC\omega^2}\right). \tag{15}$$

Solving for ω we obtain

$$\omega^2 = \frac{1}{LC\left(1 + \frac{2M}{L}\cos\frac{s\pi}{n-1}\right)}. \tag{16}$$

By assigning to s all the values from 1 to n, we get the values of the resonance frequencies of the system, which are, of course, also the free vibration frequencies of the system.

For two coupled circuits we have by (16)

$$\left.\begin{aligned}\omega_1 &= \frac{1}{\sqrt{LC\left(1 + \frac{M}{L}\right)}},\\ \omega_2 &= \frac{1}{\sqrt{LC\left(1 - \frac{M}{L}\right)}}.\end{aligned}\right\} \tag{17}$$

For three coupled circuits

$$\left.\begin{aligned}\omega_1 &= \frac{1}{\sqrt{L\,C\left(1+\frac{M\sqrt{2}}{L}\right)}},\\ \omega_2 &= \frac{1}{\sqrt{LC}},\\ \omega_3 &= \frac{1}{\sqrt{L\,C\left(1-\frac{M\sqrt{2}}{L}\right)}}.\end{aligned}\right\} \tag{18}$$

For four coupled circuits, the four values of ω are

$$\left.\begin{aligned}\omega_1 &= \frac{1}{\sqrt{L\,C\left(1+1.618\,\frac{M}{L}\right)}},\\ \omega_2 &= \frac{1}{\sqrt{L\,C\left(1+0.618\,\frac{M}{L}\right)}},\\ \omega_3 &= \frac{1}{\sqrt{L\,C\left(1-0.618\,\frac{M}{L}\right)}},\\ \omega_4 &= \frac{1}{\sqrt{L\,C\left(1-1.618\,\frac{M}{L}\right)}}.\end{aligned}\right\} \tag{19}$$

It is obvious from the above that the current in a system of coupled circuits as a function of frequency will have a number of maxima corresponding to the number of circuits. As the number of circuits is increased these maxima come closer and closer together, and for a large number of circuits they practically coalesce and the system is in resonance for the entire range of frequencies from ω_1 to ω_n, and this gives the effect of band tuning. Even for a limited number of circuits the maxima are not far apart and the system approximates the condition of band tuning. It is evident from the expression for ω given by (16) that the difference between the extreme frequencies corresponding to ω_1 and ω_n becomes greater as the number of circuits is increased. In the limit when the number of circuits is infinite, the extreme frequencies have the following values:

$$\left.\begin{aligned}f_1 &= \frac{\omega_1}{2\pi} = \frac{1}{2\pi\sqrt{LC\left(1+\frac{2M}{L}\right)}},\\ f_n &= \frac{\omega_n}{2\pi} = \frac{1}{2\pi\sqrt{LC\left(1-\frac{2M}{L}\right)}}.\end{aligned}\right\} \tag{20}$$

In a limited number of electromagnetically coupled circuits the width of the frequency band is always less than the frequency difference $\omega_1 - \omega_n$ given by the values of ω_1 and ω_n above, approaching this condition as the number of circuits is indefinitely increased.

Considering the problem from the standpoint of an artificial line, the number of circuits large to give the equivalent condition of a line, we make use of equation (5)

$$\varepsilon^{\gamma} + \varepsilon^{-\gamma} = \frac{-Z}{Mj\omega}. \tag{5}$$

Put for convenience

$$\frac{Z}{2Mj\omega} = K, \tag{21}$$

and solve for ε^{γ} and $\varepsilon^{-\gamma}$, we obtain

$$\left.\begin{aligned} \varepsilon^{\gamma} &= -K + \sqrt{K^2 - 1}, \\ \varepsilon^{-\gamma} &= -K - \sqrt{K^2 - 1}. \end{aligned}\right\} \tag{22}$$

If $K^2 < 1$, that is

$$-1 < K < 1, \tag{23}$$

$$\left.\begin{aligned} \varepsilon^{\gamma} &= -K + j\sqrt{1 - K^2}, \\ \varepsilon^{-\gamma} &= -K - j\sqrt{1 - K^2}. \end{aligned}\right\} \tag{24}$$

Put $\gamma = \alpha + j\beta$, and the above equations take the form

$$\left.\begin{aligned} \varepsilon^{\alpha}(\cos\beta + j\sin\beta) &= -K + j\sqrt{1 - K^2}, \\ \varepsilon^{-\alpha}(\cos\beta - j\sin\beta) &= -K - j\sqrt{1 - K^2}. \end{aligned}\right\} \tag{25}$$

From either of the above equations, we get the values of α and β as follows:

$$\begin{aligned} \varepsilon^{\alpha} = \varepsilon^{-\alpha} &= 1, \\ \cos\beta &= -K, \end{aligned}$$

that is

$$\left.\begin{aligned} \alpha &= 0, \\ \beta &= \cos^{-1}(-K). \end{aligned}\right\} \tag{26}$$

For values of K between the limits -1 and $+1$ as given by (23), the attenuation is zero, no reduction in intensity of the current as it passes from one circuit to another. The range of frequencies for which there is no attenuation can be readily deter-

mined from the relation $K = \pm 1$. If each circuit consists of an inductance and capacity in series, we have

$$K = \frac{-Z}{2Mj\omega} = \frac{-Lj\omega}{Mj\omega}\left(1 - \frac{1}{LC\omega^2}\right) = \pm 1, \tag{27}$$

and

$$\omega^2 = \frac{1}{LC\left(1 \pm \frac{2M}{L}\right)}. \tag{28}$$

That is, the band of frequencies for which there is no attenuation lies in the frequency region, the limits of which are

$$\left.\begin{aligned} f_1 = \frac{\omega_1}{2\pi} &= \frac{1}{2\pi\sqrt{LC\left(1 + \frac{2M}{L}\right)}}, \\ f_n = \frac{\omega_n}{2\pi} &= \frac{1}{2\pi\sqrt{LC\left(1 - \frac{2M}{L}\right)}}. \end{aligned}\right\} \tag{29}$$

The same result as given by equations (20).

For $\frac{M}{L} = \frac{1}{2}$, equations (20) or (29) reduce to

$$\left.\begin{aligned} f_1 &= \frac{1}{2\pi\sqrt{2LC}}, \\ f_n &= \infty. \end{aligned}\right\} \tag{30}$$

The system is in resonance for all frequencies above f_1, permitting currents of all these frequencies to pass without attenuation. From the standpoint of coupled circuits this result may be interpreted as the reactance of the system being zero for all frequencies within the limits f_1 and ∞.

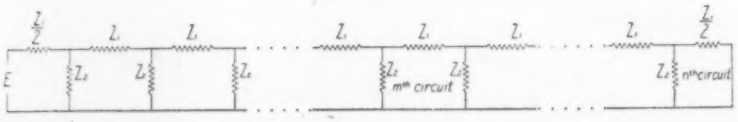
A system of an infinite number of coupled circuits has an infinite number of degrees of freedom and has accordingly an infinite number of free periods of oscillations and will therefore be in resonance for impressed electromotive forces of frequencies corresponding to the free periods of the system. If the free periods of the system are limited to a finite range as given in the case above by the conditions of equations (20), the frequencies corresponding to the free periods of the system are close together, and we have the condition of band tuning. For a limited number of circuits the resonance frequencies are closer or farther apart, depending on the number of circuits, and the condition of band tuning is approximated if an appreciable number of circuits is

used. The electric filter is nothing more, of course, than a system of coupled circuits; the character of the coupling is immaterial, and should be considered as such. It is believed that looked at from the standpoint of coupled circuits, the physical interpretation of the operation of the electric filter is immediately obvious, and the explanation of its properties much simplified.

DIRECT COUPLED SYSTEM.

The general principles discussed above in connection with an electromagnetic coupled network of circuits are applicable to any system of circuits irrespective of the type of coupling adapted. The following is a brief discussion of a direct coupled system,

FIG. 2.



shown in Fig. 2, which is the most common arrangement used in the design of electric filter circuits.

The formulas are much simplified if the series reactances of the two end circuits are each assumed one-half the series reactance of any intermediate circuit.

The electromotive forces acting in each of the circuits except the end circuits is given by the following equation:

$$Z_1 I_m + Z_2 I_m - Z_2 I_{m+1} - Z_2 I_{m-1} + Z_2 I_m = 0,$$

or

$$(Z_1 + 2Z_2) I_m - Z_2 I_{m+1} - Z_2 I_{m-1} = 0. \tag{31}$$

For the two end circuits, the first and nth circuit, we have

$$\left.\begin{aligned} \frac{1}{2} Z_1 I_1 + Z_2 I_1 - Z_2 I_2 &= E\varepsilon^{j\omega t}, \\ \frac{1}{2} Z_1 I_n - Z_2 I_{n-1} + Z_2 I_{n+1} &= 0. \end{aligned}\right\} \tag{32}$$

The solution of equation (31) is

$$I_m = A\varepsilon^{m\gamma} + B\varepsilon^{-m\gamma}, \tag{33}$$

which yields the relation

$$\varepsilon^{\gamma} + \varepsilon^{-\gamma} = 2 + \frac{Z_1}{Z_2},$$

or

$$\cosh \gamma = 1 + \frac{1}{2} \frac{Z_1}{Z_2}. \tag{34}$$

The constants A and B are determined from equations (32) by substituting the values of I_m from (33), which gives the following

$$\left.\begin{aligned}\left(\tfrac{1}{2}Z_1+Z_2\right)\left(A\varepsilon^{\gamma}+B\varepsilon^{-\gamma}\right)-Z_2\left(A\varepsilon^{2\gamma}+B\varepsilon^{-2\gamma}\right)&=E\varepsilon^{j\omega t},\\ \left(\tfrac{1}{2}Z_1+Z_2\right)\left(A\varepsilon^{n\gamma}+B\varepsilon^{-n\gamma}\right)-Z_2\left(A\varepsilon^{(n-1)\gamma}+B\varepsilon^{-(n-1)\gamma}\right)&=0.\end{aligned}\right\} \tag{35}$$

Rearranging, the above simplify as follows:

$$\left.\begin{aligned}A\varepsilon^{\gamma}+B\varepsilon^{-\gamma}&=\frac{-2E\varepsilon^{j\omega t}}{Z_2(\varepsilon^{\gamma}-\varepsilon^{-\gamma})},\\ A\varepsilon^{n\gamma}+B\varepsilon^{-n\gamma}&=0.\end{aligned}\right\} \tag{36}$$

The constants A and B are readily determined from the above two equations

$$\left.\begin{aligned}A&=\frac{2E\varepsilon^{j\omega t}\varepsilon^{-n\gamma}}{Z_2(\varepsilon^{\gamma}-\varepsilon^{-\gamma})(\varepsilon^{(n-1)\gamma}-\varepsilon^{-(n-1)\gamma})},\\ B&=\frac{2E\varepsilon^{j\omega t}\varepsilon^{n\gamma}}{Z_2(\varepsilon^{\gamma}-\varepsilon^{-\gamma})(\varepsilon^{(n-1)\gamma}-\varepsilon^{-(n-1)\gamma})}.\end{aligned}\right\} \tag{37}$$

Substituting these values in (33), we finally get the expression for the current in any circuit

$$I_m=\frac{2E\varepsilon^{j\omega t}\left\{\varepsilon^{(n-m)\gamma}+\varepsilon^{-(n-m)\gamma}\right\}}{Z_2(\varepsilon^{\gamma}-\varepsilon^{-\gamma})(\varepsilon^{(n-1)\gamma}-\varepsilon^{-(n-1)\gamma})}. \tag{38}$$

$$I_m=\frac{E\varepsilon^{j\omega t}\cosh(n-m)\gamma}{Z_2\sinh\gamma\sinh(n-1)\gamma}. \tag{39}$$

For the last circuit, $m=n$,

$$I_n=\frac{E\varepsilon^{j\omega t}}{Z_2\sinh\gamma\sinh(n-1)\gamma}. \tag{40}$$

The current is of maximum value, the system is in resonance when the reactance part of the denominator in equation (40) vanishes. Neglecting the resistance of the circuits, the resonance condition is

$$\sinh(n-1)\gamma=0, \tag{41}$$

and

$$(n-1)\gamma=js\pi,\ s=0,1,2,3,\cdots n-1. \tag{42}$$

For values of $s>n-1$ we get only a repetition of the values corresponding to s between 0 and $n-1$, and no new terms added.

To determine the frequencies which correspond to the values of γ given by (42) for any system of circuits, we use equation (34),

$$\cosh \gamma = 1 + \frac{1}{2}\frac{Z_1}{Z_2},$$

or

$$\cos \frac{s\pi}{n-1} = 1 + \frac{1}{2}\frac{Z_1}{Z_2} \tag{43}$$

Different inductance capacity arrangements in the series and shunt reactances Z_1 and Z_2 will give different results. By way of illustration we shall consider here several simple cases:

Case I. Inductance in series branch, capacity in shunt branch.

$$Z_1 = Lj\omega, \; Z_2 = \frac{1}{Cj\omega},$$

$$\cos \frac{s\pi}{n-1} = 1 - \frac{1}{2} LC\omega^2,$$

$$\omega^2 = \frac{2\left(1 - \cos \frac{s\pi}{n-1}\right)}{LC}. \tag{44}$$

For two sections, $n = 2$,

$$\omega_1 = 0,$$

$$\omega_2 = \frac{2}{\sqrt{LC}}$$

For three sections, $n = 3$,

$$\omega_1 = 0, \; \omega_2 = \frac{\sqrt{2}}{\sqrt{LC}}, \; \omega_3 = \frac{2}{\sqrt{LC}}.$$

For four sections, $n = 4$,

$$\omega_1 = 0, \; \omega_2 = \frac{1}{\sqrt{LC}},$$

$$\omega_3 = \frac{\sqrt{3}}{\sqrt{LC}}, \; \omega_4 = \frac{2}{\sqrt{LC}}.$$

As the number of sections is increased, the number of frequencies for which the system is in resonance is correspondingly increased; all the frequencies, however, being within the same frequency limits $f_1 = 0$ and $f_n = \frac{2}{\sqrt{LC}}$. For an infinite number of sections the system is in resonance for an infinite number of frequencies within a limited band of frequencies, which in the above case would be for all frequencies below the frequency

$$f_n = \frac{1}{\pi\sqrt{LC}}.$$

Case II. Capacity in series branch, inductance in shunt branch.

$$Z_1 = \frac{1}{Cj\omega}, \quad Z_2 = Lj\omega,$$

we have by (43)

$$\omega^2 = \frac{1}{2LC\left(1 - \cos\frac{s\pi}{n-1}\right)} \tag{45}$$

For two sections, $n = 2$,

$$\omega_1 = \infty,$$

$$\omega_2 = \frac{1}{2\sqrt{LC}}.$$

For three sections, $n = 3$,

$$\omega_1 = \infty, \quad \omega_2 = \frac{1}{\sqrt{2LC}}, \quad \omega_3 = -\frac{1}{2\sqrt{LC}}.$$

For four sections, $n = 4$,

$$\omega_1 = \infty, \quad \omega_2 = \frac{1}{\sqrt{LC}}, \quad \omega_3 = \frac{1}{\sqrt{3LC}}, \quad \omega_4 = -\frac{1}{2\sqrt{LC}}.$$

For an infinite number of sections, the system is in resonance for an infinite number of frequencies, that is, for all frequencies above the frequency $f = \frac{1}{4\pi\sqrt{LC}}$. The limiting frequencies for which the system is in resonance are the same in all cases irrespective of the number of sections used.

Case III. Series inductance-capacity in series branches, parallel inductance-capacity in shunt branches.

$$Z_1 = L_1 j\omega + \frac{1}{C_1 j\omega} = L_1 j\omega\left(1 - \frac{1}{L_1 C_1 \omega^2}\right),$$

$$Z_2 = \frac{L_2 j\omega}{1 - L_2 C_2 \omega^2}.$$

For

$$L_1 = L_2, \quad C_1 = C_2,$$

$$\frac{Z_1}{Z_2} = \frac{2LC\omega^2 - L^2C^2\omega^4 - 1}{LC\omega^2}.$$

Substituting the above in (43), we get

$$\cos\frac{s\pi}{n-1} = \frac{4LC\omega^2 - L^2C^2\omega^4 - 1}{2LC\omega^2},$$

and

$$\omega^2 = \frac{2 - \cos\frac{s\pi}{n-1} \pm \sqrt{\left(2 - \cos\frac{s\pi}{n-1}\right)^2 - 1}}{LC}. \tag{46}$$

For two sections, $n = 2$,

$$\omega_1 = \frac{1}{\sqrt{LC}},$$
$$\omega_2 = \sqrt{\frac{3 \pm \sqrt{8}}{LC}}.$$

For three sections, $n = 3$,

$$\omega_1 = \frac{1}{\sqrt{LC}},$$
$$\omega_2 = \frac{\sqrt{2 \pm \sqrt{3}}}{\sqrt{LC}}, \qquad (46)$$
$$\omega_3 = \frac{\sqrt{3 \pm \sqrt{8}}}{\sqrt{LC}}.$$

For four sections, $n = 4$,

$$\omega_1 = \frac{1}{\sqrt{LC}}, \quad \omega_2 = \frac{\sqrt{\frac{1}{2}(3 \pm \sqrt{5})}}{\sqrt{LC}}$$

$$\omega_3 = \frac{\sqrt{\frac{1}{2}(5 \pm \sqrt{21})}}{\sqrt{LC}}, \quad \omega_4 = \frac{\sqrt{3 \pm \sqrt{8}}}{\sqrt{LC}}.$$

For an infinite number of sections the system is in resonance for an infinite number of frequencies, the extreme limits of which are $f_1 = \frac{1}{2\pi}\sqrt{\frac{3-\sqrt{8}}{LC}}$ and $f_n = \frac{1}{2\pi}\sqrt{\frac{3+\sqrt{8}}{LC}}$, all the frequencies between these limits pass freely. It is to be noted that in this case because each section consists of an inductance capacity in the series branch and an inductance capacity in the parallel branch, each section is in itself a double periodic system, and hence for n sections the system is in resonance for $2n$ frequencies. If $Z_1 \neq Z_2$ the system is in resonance for two distinct and separate bands of frequencies. By making $Z_1 = Z_2$, as we have done in the above case, the two frequency bands coalesce and one frequency is common to the two bands of frequencies. The number of frequencies for which the system is in resonance is reduced by one, that is, for n sections the resonance frequencies of the system are $2n - 1$. In this case the frequency $f = \frac{1}{2\pi\sqrt{LC}}$ is the common frequency of the two bands.

It is evident from the above considerations that no matter what type of circuit connections is used in electric filter circuits, it is in all cases the equivalent of a system of coupled circuits. The system is in resonance for a number of frequencies, within the frequency limits determined by the electrical constants of the circuits, corresponding to the number of individual circuits used. The ideal condition of band frequency tuning can be realized only with an infinite number of circuits, but this condition is approximated even when only a limited number of circuits is used.

The Effect of Temperature on Gravitative Attraction. P. E. SHAW and N. DAVY. (*Proc. Royal Soc.*, A 714.)—"Previous work by one of us with a torsion balance of the Boys-Cavendish type had appeared to indicate that the so-called Newtonian Constant of Gravitation increases slightly as the attracting bodies are heated. The attempt has now been made to carry the work to a higher order of accuracy with a view to confirming or disproving that result. The clearing up of this point has become of greater importance on account of the recent development in the theories of gravitation." The greatest care was exercised to exclude tremors originating in distant trains from the apparatus. This having been accomplished, an elevation of temperature from 0° to 250° made no change in the value of the gravitational constant. The authors are of the opinion that "slight displacements of the heavy masses occurring during the experiments introduced systematic errors in the former work."

G. F. S.

On the Susceptibility of Feebly Magnetic Bodies as Affected by Compression. ERNEST WILSON. (*Proc. Royal Soc.*, A 712.)—This investigation may "possibly throw some light upon the susceptibility of the earth's crust as affected by the enormous forces with which it has to contend, and their variations." The stresses applied were all compressive and extended to about 1200 kilograms per square centimetre.

The susceptibility was measured at right angles to the stress and also along it. In the former direction some small increases were noted as the stress increased. In the case of a dolerite the increase was as much as 10 per cent., while no change at all was found in the specimen of New York magnetite which manifested the largest change in longitudinal susceptibility. This property for this particular ore of iron diminished to half of its initial value upon the application of pressure. Other magnetites from Arkansas and Manchuria showed an effect in the same direction but to a very small degree. G. F. S.

AN IMAGINARY THERMODYNAMIC PROCESS.*

BY

JOSEPH S. AMES, Ph.D., LL.D.

Director, Physical Laboratory, Johns Hopkins University, Baltimore, Maryland.
Associate Editor, Member of the Institute.

In presenting to students the concept of entropy and in emphasizing the essential steps in the logical development of the subject, great difficulties are encountered, as every teacher knows, owing to the refusal on the part of most men's minds to appreciate the meaning of things about which their senses give them no information. Strange to say, students accept without a qualm such words as "energy," "electricity," "unit pole of magnetism," etc., and yet draw back in alarm from "entropy." They seem to require a picture, and do not hesitate to supply their own; for entropy they have none.

I have found that a somewhat similar problem to that of the Carnot-Clausius one could be developed in such a manner as often to help a student to overcome his reluctance to adopt the concept of entropy. Just why this is so, I do not know.

In the proof of the existence of a property which is called entropy, the method usually followed is to consider two Carnot engines, whose operation is described on a pressure-volume diagram by means of isothermals and adiabatics. If an analysis is made of the instruments and fundamental concepts required, it will be found to include the following:

(1) Concept of a substance all of whose properties are defined by a knowledge of two, *e.g.*, pressure and volume.

(2) Instruments to measure pressure and volume.

(3) A thermoscope to indicate when the temperature of a body is kept constant and if two bodies have different temperatures. (There is no need of having a temperature scale.)

(4) A knowledge of what is meant by work done by mechanical forces, *e.g.*, in the case of an expanding fluid, $\Delta W = pdV$.

(5) A means of measuring heat-quantities, *i.e.*, the amount of energy transmitted by the processes of radiation and conduction.

(6) Two "baths," or reservoirs, of infinite heat capacity.

* Communicated by the Author.

(7) Apparatus for varying the pressure between certain limits by a series of infinitesimal steps, *e.g.*, by use of weights.

Then isothermal and adiabatic processes may be described; the corresponding curves on a pressure-volume diagram, for any fluid, may be drawn; the conditions for a process to be performed in a reversible manner may be specified; the measurement of amounts of heat and work may be assumed possible; the first and second principles of thermodynamics will be accepted by any student; and so he is led to a definition of an "absolute" scale of temperature and to the proof of the existence of a new definite property of a body, for which the absolute value is not known, but whose changes may be measured (like potential energy). The student, as a rule, finds no difficulty till the very end. He knows—or thinks he does—about force and area, and therefore pressure; he can see that a body occupies space, so volume offers no difficulty; he has a temperature sense; he has been taught about heat, and energy, heat-engines, etc.

Now, let us assume the existence of a being who has no knowledge of space or of space measurements—but let him have sense-organs for temperature, entropy and force, and instruments for giving numbers to them; let him be able to measure the transfer of energy both by mechanical processes and by thermal processes, knowing, moreover, that, if ΔH is a small amount of heat added to a body temperature at T, and if S is its entropy, $\Delta H = TdS$ provided the proper scale of temperature is adopted. By experimenting with a tank containing some gas, which is fitted with various pistons, he could be conscious—by his force sense—of the outward thrust of the gas and of the fact that the different pistons require in general different balancing forces in order to keep them at rest. By studying various physical properties of bodies, *e.g.*, the electrical resistance of a wire, he may learn that this remains the same wherever the wire is located in the tank, but that it is different, in general, if it is placed in a gas contained in a different tank. The numerical value of this resistance may be taken to measure that property of the gas which produces the outward thrust—call this property, for convenience, "pressure." If there are two tanks, each fitted with a single piston, the two pistons being connected by a rod perpendicular to their faces, the action of the gas in one tank upon that in the other may be studied. Even if the pressure in each gas, as tested by means of

the resistance method, is the same, it will be observed that the connecting rod will, in general, be pushed one way or the other; but, by trying different pistons, two may be found such that, if they are used in the case when the two gases are at the same pressure, the double piston will not move. Then, if the pressure in one of the tanks is changed, as determined by the resistance method, the double piston will move.

(It is assumed, of course, that in the use of the resistance method care is taken to avoid temperature effects. It is also obvious that by a choice of two "standard pressure conditions" and by arbitrarily assigning numbers where necessary, a scale of pressure can be defined by $p = p_1 + \frac{r - r_1}{\frac{r_2 - r_1}{n}}$, corresponding to the ordinary definition of a temperature scale.)

The equipment of this imaginary being would then be as follows:

(1) Concept of a substance all of whose properties are defined by a knowledge of two, *e.g.*, temperature and entropy.

(2) Instruments to measure temperature on what is called the absolute scale and changes in entropy. (By assigning a number to the entropy in some standard condition, the values for any other condition would be known.)

(3) An instrument to indicate when the "pressure" of a fluid is kept constant, and if two fluids have different pressures. (There is no need of having a pressure scale.)

(4) A knowledge of what is meant by adding or withdrawing heat, *e.g.*, that $\Delta H = TdS$.

(5) A means of measuring mechanical work.

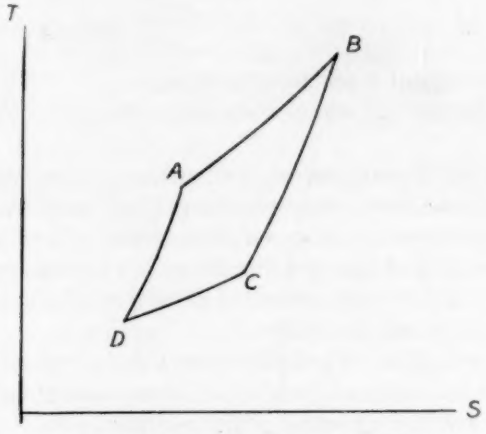
(6) Two large tanks, so large that for small displacements of their pistons there is no change in "pressure."

(7) Apparatus for varying the temperature between certain limits by a series of infinitesimal steps, *i.e.*, a series of thermal baths.

Let there be a gas container fitted with a double piston, as described above, the other piston fitting into another large tank such as specified in (6) above; let each tank be provided with resistance coils and let conditions be adjusted until the "pressure" in both gases is the same. Let the temperature of the "working substance," *i.e.*, the gas in the container, be T and its entropy S,

the container being surrounded by a bath at the same temperature. It is a condition of mechanical and thermal equilibrium, and can be described by a point A on a temperature-entropy diagram. By adding small quantities of heat to the gas in the container, by placing the container in a thermal bath at temperature $T + dT$, etc., its temperature and entropy will both increase gradually, while its "pressure" remains unchanged, owing to its connection with the large tank. In this manner an "isobar," AB, may be described by the gas in the container. The process will be reversible if each point of the curve represents a condition of equilibrium, that is,

FIG. 1.



Elementary cycle on temperature-entropy diagram.

if the experimenter has at his disposal a series of "baths" with which to surround the container, whose temperatures vary by infinitesimal steps from T_A to T_B. In the process the amount of heat withdrawn from the baths and added to the gas is $\int TdS$, or the area between the curve and the axis of entropy; and a certain amount of work W_1 has been done on the gas contained in the large tank, which may be called P_1 tank. When the gas has reached a certain state described by the coördinates of B, let the piston of the gas container be clamped. Then, by a series of steps, heat may be withdrawn from the gas, until its temperature and entropy are lowered to the corresponding coördinates of a point C, the curve described being called an "argonic," because no

mechanical work is done. (The process may be made in a reversible manner if a series of suitable thermal baths are used.) The argonic is steeper than the isobar because in the former process when heat is added or subtracted all the energy is used for the change in temperature of the gas, and therefore a given change in entropy corresponds to a greater change in temperature. When the gas is in the condition C, its double piston may be fitted into a different large tank, which may be called P_2, so chosen that its "pressure" is the same as that of the gas itself in the condition C. The piston may now be unclamped; heat may be withdrawn from the gas—by a reversible process if desired—until the gas reaches a condition indicated by the coördinates of the point D. In this isobaric process heat is added to the baths, and the gas in the large tank P_2 does a certain amount of work, W_2. When the condition D has been reached, the piston may be again clamped; and if heat is added to the gas by infinitesimal steps, an argonic will be described. If the "stroke" CD is suitably chosen, this argonic will pass through the initial point A. A cycle will have been described by the working substance, the gas in the container. In the cycle the net amount of heat withdrawn from the baths and added to the gas is $H = \int TdS$ around the cycle, *i.e.*, it equals the area of the cycle on the diagram. The gas in tank P_1 has had an amount of work done on it equal to W_1, and that in tank P_2 has done an amount of work W_2. Therefore, by the conservation of energy

$$H + W_2 = W_1$$

or

$$H = W_1 - W_2$$

Similarly, another gas container, with a different gas, may be made to describe a cycle making use of the *same* two tanks P_1 and P_2. Let the amounts of heat and work involved be called H', W'_1 and W'_2. Then,

$$H' = W'_1 - W'_2$$

It has been noted that all the processes involved in the two cycles may be performed in a reversible manner; so, if the first cycle is reversed, the net result is that the net heat added to the

baths, being withdrawn from the gas, is H; the gas in tank P_1 does work W_1, and the gas in tank P_2 has work W_2 done on it. Therefore

$$W_1 = W_2 + H$$

or, of course,

$$H = W_1 - W_2$$

If the "strokes" of the two cycles are chosen suitably, their areas may be made the same; so the net amounts of heat involved in the two cycles are the same, *i.e.*, $H = H'$. Then, if the first cycle is performed in a reverse sense, and the second cycle in a direct sense, the net result is that the gas in tank P_1 has done an amount of work $W_1 - W'_1$ and that in tank P_2 has received an equal amount of energy $W_2 - W'_2$. In performing the various steps in the two cycles, heat has been added or taken from various thermal baths and therefore their entropies have been changed; but, since the net amount of heat H' added to the working substance in the second cycle equals the net amount of heat H taken away from the working substance in the first cycle when reversed, there are quantities of heat available which may be taken from or added to the thermal baths, so as to restore them to their former entropies. By processes of radiation this restoration would result in leaving the hottest bath used in a condition of having lost an amount of heat, and the coldest bath used in a condition of having added to it an equal amount. To complete the restoration, our imaginary being must be able to reverse this, *i.e.*, to take away heat from the cold bath and add it to the hot one, *without doing any mechanical work*. This power, then, is assumed; it is not contrary to the conservation of energy. (Compare, Maxwell's "demon.") Consequently at the end of the combined cyclical processes, cycle one reversed and cycle two direct, the only changes in the whole "apparatus" are: Gas in tank P_1 has done an amount of work $W_1 - W'_1$; gas in tank P_2 has had done upon it an equal amount of work $W_2 - W'_2$.

Experience with two tanks containing gases at different "pressures" would convince the observer that, if one is allowed to do work upon the other, connecting them by means of a double piston, the result is always in a definite direction. That is, if R_1 is the electrical resistance of the "pressure indicator" when placed in one tank; and, if R_2 is its resistance when placed in the other, experiments will show that, if $R_1 = R_2$, no work is done, and that,

if $R_1 \neq R_2$ in all cases work is done *by* the tank for which R is the greater, or for which R is the less. Experiments will decide which of these two is correct—it will depend upon the type of pressure indicator selected; but the result is always definite and unidirectional. The tank which *does the work* is said to have the "higher pressure." Other experiments will show that, if a gas is in a container whose piston is clamped, and, if heat is added to it, the "pressure" is thereby increased. This proves that in the case of the cyclical processes discussed previously the pressure in tank P_1 is higher than in the tank P_2.

The experiments just referred to may be described by saying that, if there are two tanks at different pressures and if the only change taking place in nature consists in the gas in one tank doing work and in work being done on the gas in the other, the gas in the tank at the higher pressure is the one that does the work. In other words, if there are two pressure tanks at different pressures, the gas at low pressure cannot do work upon the other, provided there are no other changes in the system. In the case of the combination of the two cycles previously described, the gas in tank P_1, the one having the higher pressure, does the work $W_1 - W'_1$; and, therefore, in accordance with this principle, this cannot be a negative quantity; hence

$$W_1 - W'_1 \geq 0$$

Similarly, if the first cycle is performed in a direct manner, and the second in a reverse one, the work done by the gas in the tank at the higher pressure is $W'_1 - W_1$, and hence

$$W'_1 - W_1 \geq 0$$

It follows, then, that $W_1 = W'_1$, when H is made equal to H'; and therefore the ratios $\frac{H}{W_1}$ and $\frac{W_2}{W_1}$ are the same, regardless of the working substance used or of the length of the stroke, for all cycles made up of reversible isobaric and argonic processes, use being made of the same two pressure tanks P_1 and P_2.

[This same theorem may be deduced in a different manner. Let the stroke of the two cycles be adjusted until $W_2 = W'_2$. Then, if the first cycle is reversed and combined with the second performed directly, the net result is that the mechanical work done

is by the gas in tank P_1 alone, being $W_1 - W'_1$, and that an equivalent amount of heat $H_1 - H'_1$ has been added to the thermal baths involved in performing the two cycles. Our imaginary being would find as a fact of experiment that, when the only changes in nature are processes by which the pressure in a single pressure tank is changed and heat is added to and taken from certain bodies, the process is always unidirectional, in the sense that the mechanical work done by the tank cannot be a positive quantity, *i.e.*, he has no way by which he can obtain mechanical work from a gas in a pressure tank except by letting it do work on another pressure tank. Then, in the case of the combination of the two cycles just described, $W_1 - W'_1 \leq 0$. Similarly, if the combination of cycles is reversed, $W'_1 - W_1 \leq 0$; and, therefore, $W_1 = W'_1$. Since W_2 was made to equal W'_2, $H = H'$, etc.]

Since the ratio $\frac{W_2}{W_1}$ depends only upon the pressure conditions in the two tanks; that is, since the numerical value of this ratio as determined by the use of any working substance is independent of this substance, it is obvious that the proper way of assigning numbers to the pressure in the two tanks is to select two such numbers p_2 and p_1, as will make

$$\frac{p_2}{p_1} = \frac{W_2}{W_1}$$

If some standard pressure condition is adopted and if a definite number is assigned to this, then the number for the pressure of any other condition (*e.g.*, in a pressure tank) is definite.

Using this "absolute" scale of pressure, a simple cycle on the *T-S* diagram is described by the equation

$$\frac{W_1}{p_1} = \frac{W_2}{p_2}$$

in which W is the mechanical work done by (or upon) the working substance while it is at a pressure p.

In any one of the original cycles, consisting of two isobars and two argonics, the $\int \frac{\triangle W}{p}$ around the cycle equals $\frac{W_1}{p_1} - \frac{W_2}{p_2}$ and therefore is zero. Any cycle on the temperature-entropy diagram can be regarded as the summation of a number of such elementary cycles; and, since $\int \frac{\triangle W}{p}$ around a cycle equals zero, there must be

a "property" of the working substance such that, calling its numerical value by the symbol V,

$$\frac{\triangle W}{p} = dV$$

i.e., the work done by the substance while this property is increasing by an amount dV, its pressure being p, is given by $\Delta W = pdV$. This new property, whose "existence" is deduced from indirect observations, may be called "volume."

It is obvious that all that is given by the equation of definition is a knowledge of dV, *i.e.*, the change in volume. To obtain a value for the volume itself, V, it is necessary to assign a number V_0 to the volume of the substance under some standard condition of temperature and entropy, and then $V = V_0 + \int_0 \frac{\triangle W}{p}$, where the integral is taken along a "reversible path." (Of course the actual value of V in any condition does not depend upon the use of reversible processes to reach it; but, if one wishes to know the value, it is necessary to use them.)

An Experimental Investigation of the Dispersion of a Limited Wave Train. I. H. SOLT. (*Phys. Rev.*, December, 1922.)—When an electromagnetic wave passes from one medium to another certain things take place that are not in accord with the common conception of dispersion and refraction. "In the neighborhood of an absorption band the index of refraction of a dispersing medium may be less than unity and consequently the velocity with which a given wave crest in a monochromatic wave train is propagated may exceed its velocity in a vacuum. This is true only after the medium has reached a steady state, *i.e.*, theoretically, for an infinite wave train. From this one might conclude that a signal could be sent with a velocity greater than the velocity of light in vacuum in contradiction to the principle of relativity." According to the theory elaborated by Sommerfeld, Brillouin and Colby, when a ray falls upon a dispersing prism, at the very earliest stage of transmission the wave front goes through with vacuum velocity and without deviation at the boundaries. "As time goes on the disturbance in the medium swings continuously toward the normal until the steady state is reached when it has the direction required by the ordinary law of refraction. The period of the first part of the disturbance is very short and the amplitude very small. Both quantities decrease with increasing obliquity, and increase as time goes on, the latter passing through a maximum and minimum before the steady state is reached."

This investigation deals with these evanescent phenomena occurring before the steady state is established. The source of energy was a Righi vibrator consisting of two steel balls actuated by two type P pliotrons in parallel giving a frequency of 170,000. The wave from the vibrator fell upon a pitch prism with a refracting angle of 30° and with faces 75 cm. high by 85 cm. long. The receiver of the transmitted energy was a crystal detector. "Since the effect we are investigating is very small and associated only with the beginning of a wave train, it is essential to use a source of radiation which emits a very large number of short wave trains per second. . . . The most convenient type of radiation to use is the highly damped wave emitted by the Righi vibrator. In this case most of the energy will be in the first period and hence the effect we are looking for will be a larger proportion of the total energy than would be the case if a longer wave train were used."

The prism was fixed. Then the receiver was moved along the arc of a circle described about a point in the axis around which the prism turned. The energy received at different positions along the arc was measured. When the ray fell on the face of the prism at right angles (angle of incidence 0°) the energy that came straight through the prism was 26 per cent. of the maximum energy found for all positions examined. As the angle of incidence was made smaller the relative proportion of the energy directly transmitted became less, as theory predicted. For an angle of incidence equal to 35° it was only 8 per cent. of the maximum amount. Upon moving the receiver from its position in the prolongation of the incident ray toward the normally refracted ray it recorded a greater and greater amount of energy received. A maximum was reached and, of course, beyond this the energy diminished. The minimum angle of deviation for all such maxima was 32°, from which the index of refraction of pitch is calculated to be 1.99. This is for waves 7.8 cm. Hertz found the index to be 1.67 for waves of length 60 cm. G. F. S.

New Lead Mineral. SAMUEL G. GORDON (*Proc. Acad. Nat. Sciences*, 1922, **74**, 101-103) describes keeleyite, a new lead mineral from the San José mine, Oruro, Bolivia. It is dark gray with a bright metallic lustre, has a specific gravity of 5.21, and occurs in crystalline aggregates which are probably orthorhombic. Keeleyite is a lead sulphantimonite (thioantimonite), and has the formula $Pb_2Sb_2O_{11}$ or $2PbS.3Sb_2S_3$. J. S. H.

Rubber-lined Steel Tanks. F. C. ZEISBERG (*J. Ind. Eng. Chem.*, 1923, **15**, 157-158) describes a steel tank which is lined with a layer of soft rubber, then a layer of hard rubber. The lining is vulcanized in position under considerable pressure. Tanks of this construction have been placed on flat cars and used for the transportation of hydrochloric acid. They may be used for the transportation of any liquid which does not attack the inner lining of hard rubber.
J. S. H.

HIGH TEMPERATURE INVESTIGATION.*

BY

EDWIN FITCH NORTHRUP, Ph.D.

Member of the Institute.

I. Up to the close of the last century science has been almost wholly occupied in a study of the properties of matter and the phenomena of energy transformations as these exist under the relatively quiescent conditions which maintain in the environment of the observers. The body of physical and chemical science has developed in nature's doldrum. Only recently have artificial means and special contrivances been employed to subject matter to the action of forces of greater magnitude, to cause energy transformations of greater rapidity, and to produce temperature variations of greater degree than occur in phenomena of natural production at the surface of the earth. The laws of physics were slowly, painfully, but progressively established from accumulated observations in laboratories to which profound reasoning and mathematical analysis were applied. The observations, however, were confined to densities, velocities, electric potentials, magnetomotive forces, temperatures, etc., easily producible without special contrivances in the restricted surroundings of the observers. The variables were varied under controlled conditions through ranges which are small indeed when compared with their possible extent as revealed by modern astrophysics. The functions of these variables, changed through narrow limits, were determined by accurate observation and brilliant deduction. Curves to express these functions were drawn for the limits of the observed variations, and the laws of physics in these limited ranges were firmly established. But imagination has too often gone hand-in-hand with experimentation. With but a trifling percentage established by observation of the long curves relating functions and variables that nature knows, scientists have dared to speculate, and formulate equations which they intend shall correctly express the entire courses of these curves. But beyond the range of observation, the

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, March 1, 1923.

true plan of nature is not revealed. The "plan of nature," when mapped out by extrapolations of short length curves drawn through points of observation, is of necessity an imaginary chart. Such extrapolations have, doubtless, a psychic value spurring research to well-directed effort, but the attitude of true science will be agnostic for all that lies in the region of pure surmise which bounds the area of actual observation.

The "new science" of physics which began to make itself strongly felt in the beginning of this century, had its inception in no changed attitude of men's minds as had the rapid advance of science in the period of the Renaissance. Then metaphysics gave place to science, and Aristotle ceased to dominate thought because there came, as it were, a gift from heaven in the form of a desire on the part of men to learn about nature through controlled observation. Francis Bacon formulated in a speculative way the new scientific method, but it was Gilbert, the father of magnetism, who first put it into effect, and reported in 1600 his successes in his classic "De Magnete." The science of nature as observed in our dwelling place, the earth, made an advance comparable to the butterfly in emerging from its chrysalis. The Newtonian laws of mechanics were firmly established for slow motions; the wave theory of light was proved—for a narrow range of wave-lengths; the electrical and magnetic properties of bodies were observed, and the laws of electricity and magnetism were rapidly formulated—for low potentials, small magnetomotive forces and where matter in the mass was under consideration; the general nature of heat, the laws of heat flow and a proper conception of temperature and its effects on matter were firmly established—for a little degree of heat concentration and a trifling range of temperature; the mechanical equivalent of heat was accurately ascertained for work expended on matter—in the mass.

With the beginning of the twentieth century there began another period of rapid advance in scientific knowledge—but of a different character. Explorations began into regions where matter exists under conditions far different than those which naturally maintain in man's abode. The constitution of matter began to be studied under circumstances exceptional on this planet and the door was opened to startling revelations.

There was no change, however, in the attitude of men's minds. The firmly rooted scientific method continued to be used. But if

the startling advance of the last two decades is not due to a changed method or to a new attitude of mind, whence came it? The answer plainly is, that our modern new science wherein the the constitution and laws of matter throughout the cognizable universe are investigated, is chiefly due to and dependent upon the invention and widening use of new and powerful tools, or instruments of research, which enable us to subject matter on earth to conditions which maintain naturally only in the skies.

When in 1892 Moissan presented to the Academy of Science his first model of an electric furnace consisting of a powerful arc housed in a chamber of quicklime, he at one bound carried inorganic chemistry into a sphere before only known in the sun's chromosphere. In his furnace which would melt tungsten he learned that every specific property of matter familiar in the range from 0° to 100° C. of temperature, which the exponents of thermotics had so thoroughly investigated, disappeared or became profoundly modified.

Inventions followed rapidly of other instruments of research with which the investigator can submit portions of matter, here on earth, to many of the conditions which are supposed to exist far below the earth's crust or in the extra mundane world. Testing machines were built to tear asunder large sections of the most tenacious steel. Pressure apparatus was devised which will squeeze a portion of matter with a pressure of 300,000 pounds per square inch, or about 20,000 atmospheres.[1] This is about ten times the explosion pressure in a large gun. The use of this apparatus has lead to many new observations on the properties of matter previously unsuspected. Yellow phosphorus, for example, becomes changed under high pressure to a brownish material of increased density and electrically conducting.

The invention of electromagnets, with which great field intensities can be produced, lead to the discovery of the Zeeman effect and to a method of measuring the ratio of the electric charge to the mass of an electron.[2]

The building of apparatus capable of supplying several kilowatts at a potential of a million volts has given a better understanding of the dielectric properties of air, the laws of corona formation, and the nature and behavior of insulators. The indus-

[1] T. W. Bridgman, *Science Abstracts*, Sec. A., No. 289, Jan. 31, 1922, p. 3.
[2] Kaye and Laby, "Phys. and Chem. Constants," p. 99.

trial value in power and voice transmission of this new knowledge is inestimable.

The invention of apparatus—the molecular vacuum pump—for extracting the last residues of gas from an evacuated space, has enabled investigators to determine the laws which govern electrons when wholly freed from matter. Perhaps no single apparatus has ever been devised with which a physical condition is carried to an extreme limit, that so profoundly affects life, as the highly evacuated electron tube.

The radioactive properties of matter appear to be independent of any physical and chemical conditions observed in nature or which can be produced in the laboratory. It is, together with gravitational attraction in this respect, unique. For its discovery no apparatus capable of producing extreme temperatures or forces was required. Nevertheless such apparatus is required to prove the lack of dependence of radioactivity upon physical and chemical forces.

In this brief survey we see that the advantages of studying the properties of matter, and transformations of energy under conditions produced artificially which approach those found in parts of the universe other than the surface of the earth are great indeed. These advantages come from a rapid increase in knowledge of the constitution of matter itself, and from an understanding of how to preserve for our uses some of the altered properties of matter brought about by extreme conditions, when normal conditions are restored. Materials which have been given permanently certain new properties often prove to be invaluable for the uses of everyday life. Thus, when silicon oxide in association with carbon is elevated to over 2000° C., silicon carbide (carborundum) is formed, and the new compound remains carborundum when the temperature is reduced to life temperature where the material with its new properties can be used in the industries.

II. Temperature is a condition under which all matter exists. It is the easiest condition to change artificially, and no change in a single condition affects to a greater extent the properties of a body. Indeed if the temperature is sufficiently raised only gravity and the radioactive properties of matter remain unaltered. Different kinds of matter when subjected for a time to high temperature have their properties permanently changed in widely different degrees. The pure elements are little affected

permanently; for when restored to the temperature from which they were raised the majority of their manifested properties and their familiar appearance return. The same is true of many very stable inorganic compounds, notably the pure oxides of the metals. Other inorganic compounds are readily disassociated by elevation of temperature and do not reassociate when the temperature is lowered. The organic non-living compounds are mostly broken down by moderate increase of temperature, and most living organic matter ends its life at about 45° C. Some organisms, oscillaria, have been reported by Morgan to live in hot springs in Iceland and at the extreme temperature for living matter of 98° C.[3]

A mere elevation of temperature if sufficient will so profoundly modify all the manifested properties of any portion of matter while at the elevated temperature, that it is difficult of recognition as the same thing. It is the retention only of the same mass, the same weight, and the same ratio of the chemical elements which it contains, by which its identity is at all recognizable.

To increase the temperature of a mass is to add to it a quantity of energy. But a mass may have its energy content increased in other ways without producing any marked physical or chemical change, as does increase of temperature. Thus, magnetizable matter is given an increase of energy content by magnetization. If the body is a dielectric it can be given an increment of energy content by electrification. All matter has its energy content increased by separating it from other matter, and all matter may become a storehouse of a considerably increased quantity of energy by imparting to it rapid motion, translatory, rotary, or both. Adding energy to a body in these ways does not, to any marked degree, affect its physical or chemical properties. But when we add energy to a body in the form of heat, thereby increasing its temperature, we always more or less profoundly change the body physically, and often chemically. Why this difference? Let us first consider a particular example. The answer will then become obvious.

Consider a steel sphere, such as is used for ball-bearings. Let us rotate this about a vertical diameter at a very high velocity. Conceivably the angular velocity of the sphere could be made very

[3] "Principles of Breeding," p. 311, by E. Davenport, published by Ginn and Co.

high by placing it in a rotary magnetic field and eliminating air friction by use of vacuum. A rotating field of almost any desired velocity of rotation could be produced by means of multiple circuits in which continuous oscillations differing in phase are maintained by means of electron tubes. By thus rotating the sphere it would be given an increment of energy. It is not to be supposed, however, that even with extremely high angular velocity imparted to the sphere, its normal properties as elasticity, density, magnetic permeability, color, etc., would be modified to any appreciable degree. The centrifugal stresses would deform it somewhat, but in all essentials it would remain the same familiar object when in rapid rotation as when at rest.

Now, with the sphere at rest, increase its temperature. Bring its increase in temperature to a point where the increase in the energy content in the form of heat of the sphere is exactly the same as was previously imparted to it in the form of kinetic energy of rotation. By this increase of energy content through increase of temperature, the properties of the steel become changed, very profoundly changed, if the temperature elevation is considerable.[4]

We readily find by calculation [4] that for a steel sphere 6 cm. in diameter, the relation holds, $N = 287\sqrt{T}$. At a temperature of about 730° C. the steel has lost its magnetic permeability, its tensile strength, and many other familiar properties, and is a red-hot body. To give the sphere the same energy content by rotation, and change none of its physical or chemical properties, it would

[4] The revolutions N per second which the sphere must make for its content of kinetic energy of rotation to equal the increase in heat energy of the stationary sphere, due to a temperature rise T is calculated thus: Energy of rotation,

$$E_r = \tfrac{1}{2} IW^2 = 2\pi^2 IN^2 = 0.8\pi^2 mr^2 N^2$$

where $I = 0.4\ mr^2$ is the moment of inertia of the sphere about a diameter, m, the mass, and r, its radius. W is its angular velocity, and N, its revolutions per second.

The heat energy imparted to the sphere by a temperature rise T is $E_h = JQ = JTms$, where $J = 4.2 \times 10^7$ ergs; m = the mass, and s = the specific heat of steel. Thus, equating these two expressions for energy content we obtain $N^2 = \frac{Js}{0.8\pi^2 r^2} T$. If we call the specific heat $s = 0.14$ and choose a sphere of radius 3 cm., we obtain finally $N = 287\sqrt{T}$. Thus, if the sphere is raised in temperature 100° C. as much energy will be added to it as would be added by imparting to the sphere 2870 revolutions per second.

have to revolve 7749 revolutions per second. It might not be possible to impart so high an angular velocity even by means of a rotating magnetic field, but the conception of this brings out the principle to be noted, which is this: In the case where the energy content is due to rotation of the sphere all ultimate particles composing the sphere are moving uniformly in circles which have a common axis. The motions of all the particles are *organized* in the sense that all move in the same direction around a common axis with the same angular velocity. The relative spacing of the particles with reference to one another remains unchanged. There is, therefore, no jostling of particles one against another, and consequently no development of atomic or molecular vibrations.

In the other case where the stationary sphere is raised in temperature by receiving an increment of heat, it acquires energy. According to the best views of science it is kinetic energy, but the total kinetic energy so received is simply the sum of the kinetic energies of motion of the countless ultimate particles which compose its mass. But now we have these ultimate particles moving at any given instant in all possible directions and with widely varying velocities. The relative spacing between particles is every instant varying. Each particle crowds for more room, and the mass expands. The particles jostle one another, and internal vibrations of atoms and electrons are established which give forth electromagnetic radiations. If the body is brought into contact with another body in which motions of its particles are less active, the first body imparts some of the motion of its particles to the second body. In other words, heat flows from the body of higher temperature to the body of lower temperature. Now we note that the unique characteristic of heat motion of particles is that the motion of all the particles is highly *disorganized* motion. In the vicissitudes of any body played upon by the forces of its environment, the least probable motion for the mass to acquire is that of a uniform translation or a uniform rotation, and only by either one or both of these motions combined can all the ultimate particles of the body become marshalled into uniform organized motion. Thus of all forms of energy which may be imparted to a mass, that form is the most probable one which gives to its ultimate particles a highly disorganized motion. All organized motions by the law of probability tend to become disorganized motions, and so we see that all forms of energy imparted to

masses tend to assume finally the form of heat. But by heat energy chiefly are physical and chemical changes produced in matter. As this type of kinetic energy is the most probable type, we must conclude that by the very laws of chance matter is destined to assume its varied forms, aspects and endless properties.

We are thus led to view increase in temperature as being a unique state acquired by every body when it receives an increment of energy in the form of increased activity of the highly disorganized motions of its ultimate particles. Increments of energy of other forms, mass velocity, magnetization, electrification, chemical separation, etc., do not produce the same state or any of the striking phenomena characteristic of it.

In this connection I am forced to ask the question, if great elevation of temperature may not so increase the velocities of atoms and the electrons within the atoms, that the masses of these latter become increased, and so the total mass of the highly heated body? Is the mass of a solid cylinder of tungsten at 3000° C. the same as at 0° C.? With modern apparatus and methods the experiment is triable.

Profound modifications of the properties of matter, often so great as to make any given portion of matter unrecognizable as the same thing, are the invariable accompaniments of a great rise of temperature—that is, of a great increase in the disorganized motions of ultimate particles. With sufficient rise of temperature the permanence of any object is lost. High temperature, in short, makes of most kinds of matter something which is entirely new; something unrecognizable as the same stuff with which we started at ordinary temperature. What undreamed of beneficent uses may not matter possess in this new dress, put on with fire!

The very conception, on the other hand, of low temperature is a picture of quiescence. The particles of matter move in short, mean paths and sluggishly. Configurations established at higher temperature are not broken up. A change of atomic partners between molecules does not occur. If the temperature falls to that of liquid helium, the motions of the molecules and atoms practically cease. The properties of a mass are greatly modified, it is true, from what they are at ordinary temperature, but the particular fact to be noted is, that with diminution of disorganized motion few property changes occur which become permanent in

the sense that when ordinary temperature is restored familiar ordinary properties do not reappear.

I do not under-rate the high value of low temperature research on the properties of matter. By such research we have penetrated deeply into a further understanding of the constitution of matter. We have discovered by such research super-conductivity, and have discovered the means of extracting helium gas in quantity; but the upper limits of the temperature scale fascinate me more, for there matter pulsates with mighty energies. It takes on aspects and strange qualities that fascinate, and the hope is ever held out of discovering in the region of high temperature unsuspected properties of matter extremely useful in the everyday affairs of industry.

Our store of knowledge, embodied in tables of constants, physical and chemical of the properties of matter above 1500° C., quantitatively expressed, is small indeed. Outside its property of giving off radiant energy, physicists and chemists have given little attention to a quantitative examination of the properties of matter exhibited at the higher temperatures. For a temperature exceeding 1000° C., very little precise information is anywhere obtainable regarding such familiar properties as surface tension, molecular cohesion, molecular adhesion, thermal expansion, specific heat, latent heat of fusion, viscosity, compressibility, elasticity, and thermal conductivity. Thermal e.m.f.'s of combinations of high fusion metals and alloys, melting and boiling points of many elements and some compounds have been studied for the higher laboratory temperatures. The resistivities of most of the non-ferrous metals have been observed by the speaker at temperatures where the metals become molten, and above—but the quantity of this data is surprisingly small. That this is so is the more surprising when we pause to consider the relative simplicity of the property manifestations of matter when at high temperature. " By passing to the high temperature range we at once eliminate from consideration all such phenomena as crystallization, magnetism, surface coloring, production of aqueous solutions, the greater part of the phenomena of organic chemistry, and a multitude of other familiar physical and chemical manifestations. The science of biology outside the range of ordinary temperatures is non-existent.

"When nature is studied, simplified, so to speak, we should be able to acquire a better understanding of the increasingly complex phenomena which appear as we bring the lower temperature range up and the higher temperature range down. In the light of our knowledge of nature simplified we shall be better able to interpret her more complex manifestations at ordinary temperatures." [5]

We cannot afford, though we consider commercial demands only, to let our tables of constants for the higher temperature ranges continue to be filled as now, with blanks in the columns.

III. Primary effects produced by great elevation of temperature in a furnace are to volatilize any readily volatilizable substances which may be present, to greatly enhance chemical activities and to promote chemical interchange of atoms. At a very high temperature the disorganized motions of ultimate material particles are so intense that a species of evaporation takes place from the surface of many highly refractory materials, loading the atmosphere of the furnace with imperfectly gasified matter. The particles of this gas may not even be molecules, but rather groups of molecules or very minute masses analogous to the carbon particles in smoke or a flame. This is notably the case where Acheson graphite is heated above 1500° C. If a glazed porcelain tube be held for a short time only in a chamber with graphite walls, thus heated, the glaze becomes blackened with the flying particles of carbon that strike and stick to it. A wire of pure tungsten held in such a chamber soon becomes brittle from carbon absorbed from the hot atmosphere. Lining the inside walls of the chamber with highly refractory non-carbonaceous material, as magnesia, will not entirely prevent these effects.

It is observed in tungsten filament lamps that the tungsten evaporates with long exposure to high temperature. Gold evaporates rapidly at a temperature considerably below its boiling point.

At extremely high temperature, almost any two compounds which differ chemically, thoria and magnesia, for example, will react when in contact.

It may be safely assumed that no refractory is pure in the sense that it will not yield vapors from slight impurities more volatile than the refractory itself, unless such refractory has been preheated to, and for some time held at, a temperature higher

[5] "A Classification of High Temperature Physical Problems," by E. F. Northrup, *Chem. and Metal. Eng.*, March, 1915.

than the temperature at which it is afterward used. Thus all materials which are to be employed as containers or heat insulators should be treated to a higher temperature than that at which they are to be used, if freedom from chemical contamination is to be secured.

If metals are to be melted and great freedom from chemical contamination is demanded, they should be fused preferably in a container made of their own oxide, where such melts higher than the metal. Thus chromium oxide would be ideal for holding molten chromium, nickel oxide for molten nickel, aluminum oxide for aluminum, etc. Where the oxide of the metal itself is not suitable, a stable oxide as magnesia or thoria should be selected, and this should be greatly preheated before using it as a container. Metals, for instance, of the platinum group may be melted in a crucible made thus without contamination.

As contamination of the product may come from gases in the furnace, melting in vacuum is often employed. It is here suggested that a substitute for vacuum melting would be to bathe the furnace chamber with pure helium gas—which forms no chemical unions.

Oxides cannot be highly heated or melted in a graphite container because most of them are reduced by the graphite, and those not reduced become blackened. A tungsten crucible heat-insulated with pure thoria is suggested as a suitable electrically conducting container for melting several refractory oxides.

By developing heat directly in the product to be heated or in the crucible wall that contains it, there is no necessity that any part of the furnace chamber shall be hotter than the product itself. As the tendency to chemical contamination increases rapidly as the temperature mounts, any arrangement whereby the charge is the hottest part of the furnace, is an important safeguard against it.

Moissan in his classic work pretty fully examined the field of high temperature chemistry and the phenomena exhibited by matter up to a temperature where lime fuses. But the value of his work was greatly diminished by one important limitation set by the nature of his furnace. This furnace was a carbon arc furnace. Carbon was always present in the atmosphere of his hot chamber, and carbides were almost invariably formed at the high temperatures at which he worked. The properties of chemically pure metals of the tungsten group were unknown to him.

In the new high temperature research of to-day, means will be employed for studying matter under controlled conditions that will avoid the clouding effects on all precision work that results from chemical contamination.

IV. The modern tools which may be used in high temperature research may be classified under: Apparatus which focuses radiation from the sun, hot flames, the electric arc, and the electric resistance furnace, vacuum bulbs which heat a surface by electron impact, and the high-frequency induction furnace.

Hot flames heat a body at its upper surface or they heat a chamber, and the heat must flow through the wall of a crucible or container to reach the product being treated. The produced temperature, therefore, must be higher than the used temperature, while the wall of the container must be sufficiently refractory to withstand the higher temperature at its outer surface. The products of combustion from a hot flame invariably subject the material being heated to contaminating influences.

I am not informed on the use which may have been made of focused sun's rays to heat a small chamber to a high temperature. The method appears as one which offers many advantages where circumstances and the hour permit of its use. Very high temperature could certainly be obtained in an oxidizing atmosphere.

The electric resistance furnace may be constructed to be free from many limitations and most objections. Where the resistor is made of a non-carbonaceous material, the temperatures ordinarily obtained are not high. However, a small chamber may be heated to a very high temperature without carbon being present, by using molybdenum or tungsten as a resistor. The tungsten tube furnace is well known. If better and less elaborate means were not available for obtaining very high, carbon-free temperatures, a furnace of this character would serve well for many kinds of investigation.

The carbon arc furnace, which is the classical device for high temperature study, is limited in usefulness because carbon is present, and the temperature, extraordinarily high, is generated in a space of very small volume. Purity of product and controllable, uniform heating are not possible. Arcs between electrodes of semi-conducting oxides and high fusing metals have been considered, but I know of no practical applications to research having been made of such.

A focused stream of electrons will give a very high temperature where it impinges, but the volume which can be heated is small, and the necessity of working with a vacuum bulb will effectually eliminate this method for obtaining practical results.

The last method, that of high-frequency induction, is in my opinion the final and the ideal method for the production under controllable conditions of any temperature from room temperature up to that of melting tungsten; especially when carbon free conditions and complete freedom from chemical contamination are required. The high temperatures obtainable, furthermore, are not localized, as in the case of an arc, to a small volume; for a space of dimensions, limited only by the electric power available, may be heated throughout its extent with uniform temperature, and the final temperature obtainable is limited not by the method, but by the refractory properties of the walls which enclose the heated zone.

It is interesting to briefly consider the fundamental principle of this method of raising the temperature of a body within an enclosure of electrically non-conducting walls. Thus, heat is said to pass from one body to another by conduction or radiation, or by both. A body also acquires heat by an internal conversion of the kinetic energy of an electric current into heat energy. Again, ferrous materials acquire heat energy by rapid reversals of their magnetism. These are more or less arbitrary classifications of the means by which a body acquires heat. If thoughtfully considered, I think it will be recognized that in all cases where a body receives heat in any other way than by direct contact with a body at higher temperature, it receives its heat primarily as an influx of electromagnetic energy. The body absorbs the electromagnetic energy which is converted within the substance of the body into that particular form of energy, which consists of highly disorganized motions of the particles and which we call heat energy. Thus radiation from the sun warms a body on which it falls, and this radiation is electromagnetic energy of short wave-length. Artificially produced electromagnetic radiation, the long wave-length radiation of radio transmission, when it falls on any body that can absorb it, heats it. The heating occurs, but as a rule, not so rapidly, when the electromagnetic waves are of great length.

If a solenoidal coil is traversed by a current which varies rapidly in magnitude the space within and surrounding the sole-

noid is alternately stored with and depleted of electromagnetic energy. This electromagnetic energy is represented by the field of force in and around the coil. The field is made visible by iron filings. The field due to a cylindrical solenoid is here shown.

If a body is placed in the solenoid, electromagnetic energy falls upon it. If the current through the coil is rapidly alternating, electromagnetic energy impinges continuously upon the body. If the body nearly fills the interior of the coil, then a large part of the electromagnetic energy which flows into the interior of

FIG. 1.

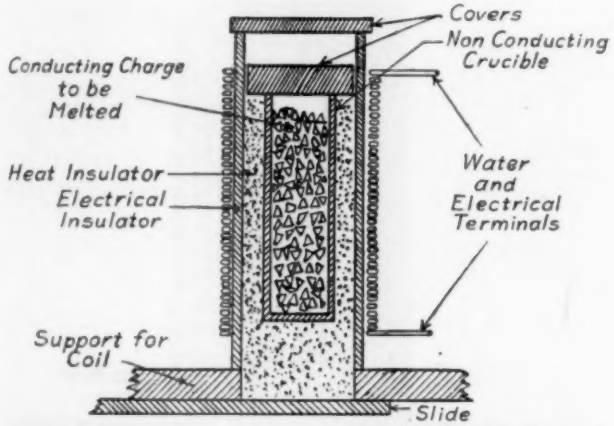
Magnetic field associated with a current-carrying single layer solenoid; made visible with iron filings.

the solenoid falls upon the body. If the body were perfectly conducting, all the electromagnetic energy which falls upon it would be reflected from its surface. If the body were a perfect dielectric, none of the energy falling upon it would be absorbed. If the body is suitably conducting then all the energy which falls upon it penetrates toward its interior being absorbed, that is, converted into heat energy, as it penetrates deeper and deeper. If the conductivity of the body is favorable all of the electromagnetic energy which enters the body is completely changed over into heat energy—and the temperature of the body rises. With constant ampere turns in the coil the rate of absorption of electromagnetic energy will be proportional to the frequency of the current. The temperature of the body will rise rapidly if it receives

energy rapidly, and will go on mounting until the body loses energy in the form of short wave-length heat radiation, as rapidly as it receives energy in the form of long wave-length electromagnetic radiation. The body accumulates heat and experiences a rise in temperature because the heat insulators which surround it are perfectly transparent to long wave-length electromagnetic radiation, and nearly opaque to the short wave-length radiation emitted by a hot body.

In this method of heating—by influx of long wave-length electromagnetic energy—the body is not joined to a source of

FIG. 2.



High-frequency induction furnace loaded with small pieces of electrically conducting material contained in a chamber with walls of non-conducting, non-carbonaceous material. Local eddy currents are induced in the individual pieces of broken material, and through the mass as a whole. These currents rapidly heat the material, and, if of a fusible nature, the entire mass is soon melted. Pure iron or platinum is readily melted in this manner, and broken pieces of pure molybdenum have likewise been fused at an estimated temperature of 2550° C

e.m.f. by electrical connections. It requires no electrodes. It can be enclosed hermetically in a vessel of dielectric material (quartz-glass, for example). This vessel can be filled with any non-metallic liquid, or any gas at any pressure which the vessel will endure, or it can be completely evacuated of everything except the body being heated.

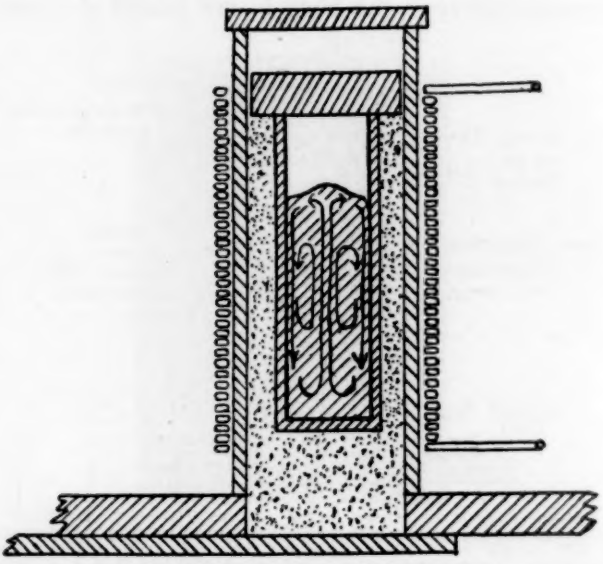
Can any method be conceived of heating a body which is more ideal, if its actual realization in practice can be effected?

V. Six years of study with much experimentation and over three years of manufacturing activities have demonstrated that the method is realizable in practice and easily so.

The details of the methods employed have been frequently described and are well known, therefore, I can only give a word here to their elucidation.

The solenoidal coil, or inductor, is generally made of a one-layer winding of flattened copper tubing from 3/8" to 1/2" in diameter. It is wound edgewise to form a cylindrical or cone-shaped coil. The inside of the solenoid is lined with a thin layer of electrically insulating material as quartz-glass, Pyrex glass, micanite, or

FIG. 3.



Here is shown in cross-section the appearance of a metal or alloy after fusion is complete. The surface of the melt is elevated at its centre. The metal circulates, rising in the region of the axis and descending in circumferential region.

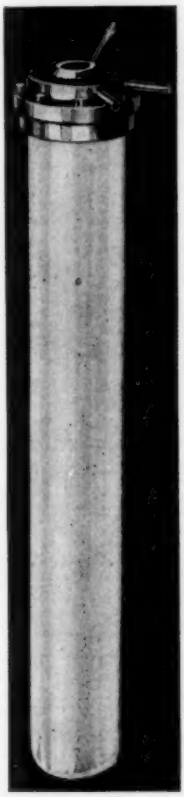
This stirring of the metal is not caused by heat, but by a mutual attraction of the current elements, the electric current induced in the melt being of greater density in the circumference of the melt than at the axis. The repulsive action of the primary upon the secondary also contributes to the stirring. This automatic circulation of the melt insures a perfect mix when alloys are melted.

asbestos board. The body to be heated is preferably chosen cylindrical or somewhat tapered when used with a conical inductor. Its outside diameter is selected to be two-thirds to three-fourths the inside diameter of the solenoid. It is placed centrally in the solenoid, and the small space between the body and the sheathing of electrical insulation which lines the inside of the inductor is filled in with finely powdered, highly refractory material. This serves as a heat insulator. A water circulation is maintained

through the hollow, flattened copper tubing which constitutes the winding. This keeps the coil cool though molybdenum be held molten within the coil.

The frequency of the electric current passed through this

FIG. 4.



This shows a quartz tube closed at the bottom, and capped with a metal cover at the top. The metal cover is water cooled. The material to be heated is placed in the lower half of this vacuum chamber. The tube fits in the inductor coil shown in Fig. 2 and Fig. 3. The air is exhausted and melts are made in vacuum.

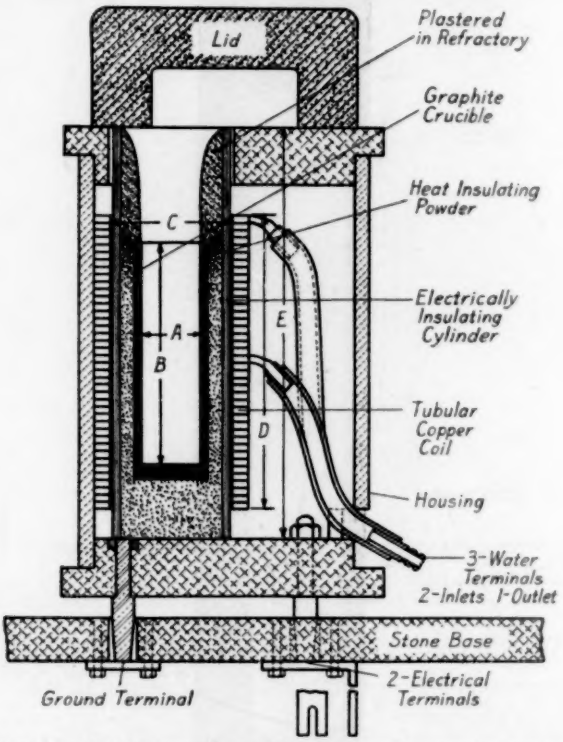
inductor is chosen high, 5000 to 50,000 cycles per second. Twenty thousand cycles is commonly employed.

Over 1000 k.w. are to-day in service heating bodies in the above fashion. If the effectiveness of the method were better appreciated, many times this amount of high-frequency power

would be used for high temperature research and for the commercial heat treatment of materials.

In melting operations the method has almost no limits imposed. Thus in actual practice 50 ounces of chemically pure platinum have been melted from a cold start in six minutes and, most important to note, entirely free from any chemical contamination.

FIG. 5.



Convenient form of high-frequency induction furnace for general research and for melting precious metals—gold, platinum, etc. The dimensions of the chamber are: *A*, 5 cm. (2"); *B*, 19 cm. (7½"). The furnace may be lifted from its base and the contents poured.

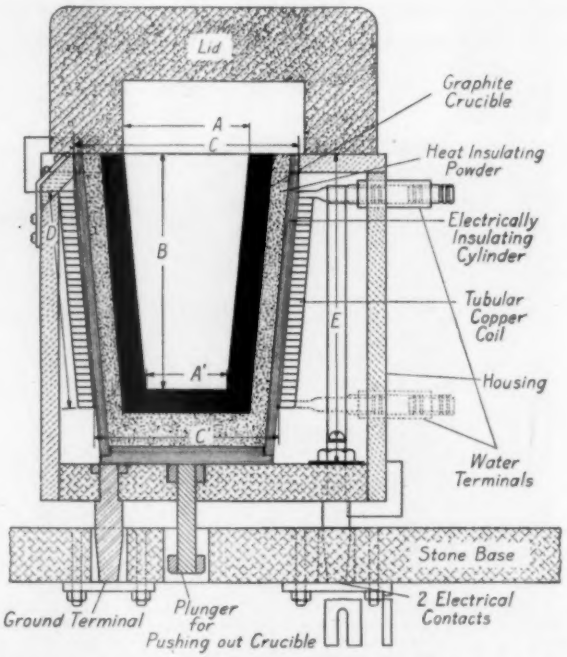
Pure iron alloyed with a large percentage of tungsten, molybdenum, etc., is being readily melted, and always carbon free, and without other chemical contaminations.

A very pure nickel-iron alloy, called permalloy, is being melted in crucibles holding 100 pounds by high-frequency induction at the rate of about 1200 pounds per day. Lower melting metals, silver, for example, are being melted in 600-pound charges.

Chambers with a wall of Acheson graphite one-fifth of a cubic foot in volume have been easily heated uniformly to a temperature which will graphitize carbon, and with an expenditure of only about 16 k.w.

Black-body chambers, which perfectly fill the conditions of the ideal black body for all manner of radiation experiments, are

FIG. 6.



Crucible type furnace used for melting or heating in a graphite chamber. Dimensions, *A*, 9 cm. (3.5″); *A'*, 5.6 cm. (2.25″); *B*, 16 cm. (6.5″).
This furnace is particularly suited to melting silver, gold, copper and their alloys. The furnace may be lifted from its base and the contents poured.

readily heated to a temperature little short of the carbon arc. If the chamber walls are of tungsten, carbon need not be present.

Some form of generator of high-frequency current to supply high-frequency power to the furnace is required, or some form of frequency converter must be used which will receive power at a commercial frequency, and deliver it at a high frequency. Apparatus of both above types are now available. For research work in the laboratory 15 kv-a. and 35 kv-a. converter sets are standardized manufactured articles. Large power sets delivering

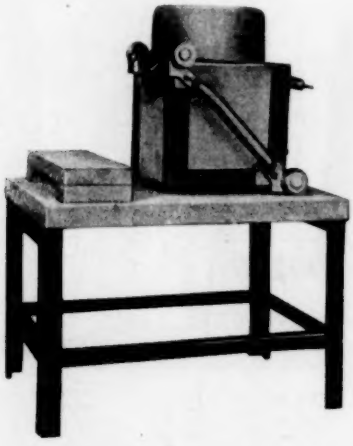
several hundred kilowatts of high-frequency power may be obtained when the commercial requirements justify the rather high cost of such equipment.

VI. No sharp lines separate low, ordinary, medium, and high temperatures. I shall call research work on the properties of matter when over 1000° C. high-temperature research.

The outstanding problems are naturally grouped into:

1. *High-temperature Chemistry.*—Here we have to consider the relative affinities of the elements when at high temperature;

FIG. 7.



Assembly view of furnace shown in Fig. 6. The side handles are grasped by the hands. The furnace is lifted from its base and the contents poured. This and the other furnaces shown are not above room temperature on the outside.

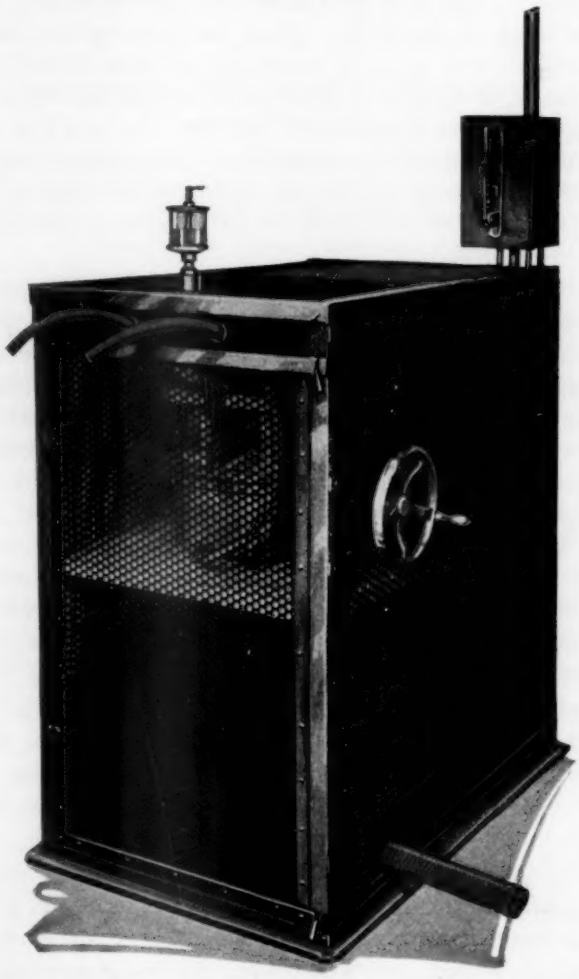
what new combinations of elements will form at different high temperatures, and which of such new-formed combinations remain unaltered when the temperature is brought back to ordinary.

High-temperature chemistry, though a very simple chemistry, has heretofore presented great difficulties in the matter of maintaining the elements and compounds under study pure. Thus accurate quantitative determinations as yet are very few. The inductive method of heating will help greatly to remove these difficulties.

2. *The Physical Properties of Matter.*—(*a*) While under the condition of high temperature; and (*b*) the new physical proper-

ties which remain at ordinary temperature, which the high-temperature treatment imparts.

FIG. 8.



General view of a 15 kv-a. high-frequency converter. This converter is placed between the current source and the furnace. It is used to change current of commercial frequency (received at the switch box shown at the top) into current of high frequency. This current is delivered by the terminals shown at the base on the right. It has no moving parts. It will supply high-frequency power for operating any of the furnaces shown in Figs. 2, 3, 5, 6, and 7.

As physical properties are very sensitive to chemical impurity, and as chemical purity at high temperature has been seldom

obtained in the past, there is great need of trustworthy information along this line.[6]

3. *Phenomena of Electronic Emission from Bodies at High Temperature.*—This is an extensive field for exploration into the region of high temperature. Thus far investigation has been chiefly confined to a study of electronic emission from hot tungsten filaments in vacuum. It is probable that all matter freely emits electrons when above 1500° or 1600° C., and that no electrical insulation is possible at and above these temperatures. The free emission of electrons from the surface of the sun, giving rise to many terrestrial and astronomical phenomena of interest, is one phase of the subject.

4. *Radiant Properties of Matter at Very High Temperature.*—This is one field of high-temperature research that physicists have much investigated. The means which are now offered for producing, with or without carbon present, a truly black-body temperature of great elevation and throughout a considerable volume in a vacuum or in any atmosphere at widely selected pressure ought to furnish great aids in a further pursuit of this line of inquiry.

VII. In conclusion, I wish to state that I have made an earnest effort to make an inventory in my mind of every avenue of physical and chemical research which promises to lead rapidly to new information of high value. I give it as my belief, after many years spent in the laboratory, that no path goes straighter or quicker to discoveries which will add much to our knowledge of matter itself, and to the finding of things useful for everyday life, than the roadway of high-temperature investigation.

I make an appeal to this generation of young, enthusiastic investigators who are students of physics and chemistry, to turn their attention and direct their efforts to a study of the region of the higher temperatures. This branch of physics and chemistry is very properly named electrothermics. Tools for work in this region are developed, and great advances in science will surely follow when departments of instruction lecture on this subject, and laboratories become equipped for experimental investigations in this fascinating and fruitful territory.

[6] Reference is suggested to "A Classification of High Temperature Physical Problems," by Edwin F. Northrup, *Chem. and Metall. Eng.*, March, 1915.

SOLUBILITY OF MANNITE IN MIXTURES OF ETHYL ALCOHOL AND WATER.*

BY

HENRY JERMAIN MAUDE CREIGHTON,

Member of the Institute,

AND

DAVID S. KLAUDER, JR.,

Department of Chemistry, Swarthmore College.

In the course of another investigation, it was necessary to know the solubility of mannite in mixtures of ethyl alcohol and water at several different temperatures. Since the data available were very meagre,[1] determinations have been made in this laboratory of the solubility of mannite in aqueous alcohols varying from 0 to 100 per cent. ethyl alcohol, at a number of temperatures between 0° and 60°.

The mannite ("Kahlbaum") used in these experiments melted at 165.9°. The alcohol employed for the solubility determinations in this solvent alone was prepared by drying 99 per cent. ethyl alcohol over lime for several months and then fractionating. The boiling point, density and refractive index of this alcohol were determined as criteria of its purity and had the following values:

$$\text{boiling point} = 78.27^\circ \ (760 \text{ mm.})$$
$$d = 0.78509$$
$$n = 1.35954$$

The different mixtures of alcohol and water were prepared by diluting 93 per cent. alcohol with the requisite amount of water.

The weight of mannite contained in a known weight of saturated solution was obtained by evaporating the solution to dryness in platinum dishes on a water-bath, drying at 110–120° and weighing the residue. Saturation in pure water and in pure ethyl alcohol was attained by boiling the finely powdered mannite and

* Communicated by Professor Creighton.

[1] Berthelot, M., *Ann. Chim. Phys.* [3], **47**, 301 (1856); Krusemann, H. D., *Ber.*, **9**, 1476 (1876).

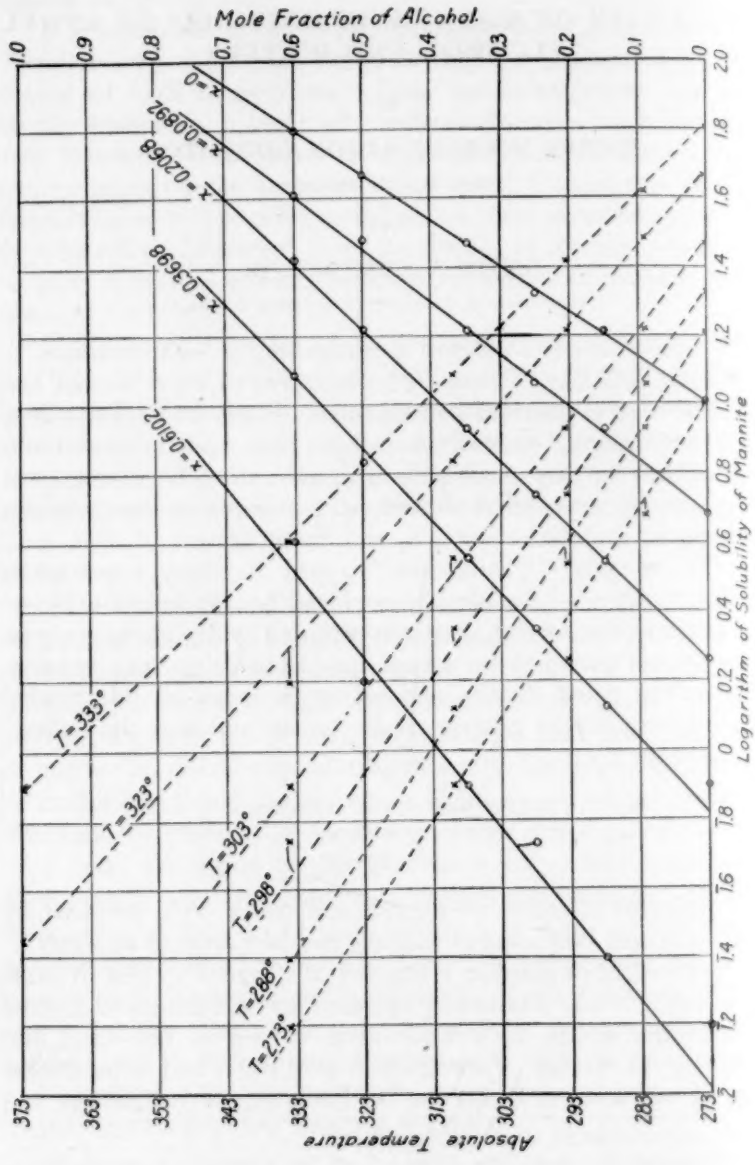

Mole Fraction of Alcohol
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
x=0
x=.00892
x=.02068
x=.03698
x=.06102
T=333°
T=323°
T=303°
T=298°
T=288°
T=273°
373
363
353
343
333
323
313
303
293
283
273
Absolute Temperature
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
T.8
T.6
T.4
T.2
T
Logarithm of Solubility of Mannite

FIG. 1.

TABLE I.

Solubility of Mannite in Mixtures of Alcohol and Water.

Per cent. by Weight of Alcohol.	0	20		40		60		80		100				
Mole Fraction of Alcohol.	0	0.0892		0.2068		0.3698		0.6102		100				
	Solubility in Grams per 100 Grams of Solvent.													
Temperature. °C.	Observed.	Observed.	Calculated.		Observed.	Calculated.		Observed.	Calculated.		Observed.	Calculated.		Observed.	Calculated.
			a	*b*		*a*	*b*		*a*	*b*		*a*	*b*		*a*
0	10.2	4.83	*5.00*	*4.94*	1.81	*1.95*	*1.90*	0.79	*0.53*	*0.50*	0.16	*0.08*	*0.07*	0.003	*0.003*
15	16.4	8.53	*8.71*	*8.27*	3.49	*3.78*	*3.58*	1.33	*1.19*	*1.06*	0.25	*0.22*	*0.18*	0.010	*0.014*
25	21.3	11.62	*11.93*	*11.84*	5.48	*5.56*	*5.48*	2.25	*1.92*	*1.88*	0.55	*0.40*	*0.39*	0.030	*0.031*
35	29.6	16.74	*17.49*	*17.35*	8.60	*8.74*	*8.59*	3.62	*3.35*	*3.24*	0.80	*0.81*	*0.77*	0.075	*0.081*
50	47.2	30.18	*30.20*	*29.90*	16.76	*16.79*	*16.36*	6.92	*7.43*	*7.09*	1.58	*2.18*	*2.07*	0.28	*0.32*
60	61.14	41.23	*43.29*	*41.86*	26.50	*25.8*	*26.1*	12.36	*12.59*	*12.73*	4.08	*4.37*	*4.45*	0.81	*0.78*

solvent for several hours in a flask having a reflux condenser. The mixture was then transferred to a bottle fitted with a stirrer which turned in a mercury seal (thus preventing loss of solvent by evaporation or admission of moisture from the air), and cooling to the desired temperature in a thermostat. Subsequently, the mixture was stirred at this temperature for five hours. In the aqueous alcohols, saturation was effected by stirring the mannite and solvent for some time at 5 to 10° above the temperature at which the solubility was to be determined. The mixture was then cooled to, and kept at, the desired temperature for a period of six to seven hours, stirring being continuous. At the end of the times mentioned, a portion of the solution was removed for analysis. Stirring was continued for two hours longer, when a second portion of the solution was removed. The weights of mannite contained in equal weights of these two portions agreed closely. The results of the solubility measurements, which represent the mean of these two weights, are contained in Table I and represented graphically in Fig. 1, where the logarithm of the solubility is plotted (1) against the absolute temperatures for different concentrations of alcohol (solid curves), and (2) against the mole fraction of alcohol for the different temperatures (broken curves). Both sets of curves are approximately linear.

The logarithm of the solubility of mannite ($\log S$) in alcohol-water mixtures, at any temperature between 0° and 60°, can be expressed as a function of the solubility in pure water (a), the mole fraction (x) of alcohol in the solvent and the absolute temperature (T), *i.e.*,

$$\log S = \log a + dx + gtx, \qquad (a)$$

where $d = -10.57$ and $g = 0.0260$. At a particular temperature between the above-mentioned limits, the logarithm of the solubility of mannite in mixtures of alcohol and water can be expressed as a function of the solubilities in the pure components and the mole fractions of the components, *i.e.*,

$$\log S = (1 - x)\log a + x \log b, \qquad (b)$$

where a and b represent the solubility of mannite in pure water and pure ethyl alcohol, respectively. Solubility values calculated by means of equations (a) and (b) are recorded in Table I in the

columns marked "*a*" and "*b*." It will be observed that, with a few exceptions, the calculated values agree fairly well with those determined by experiment.

SUMMARY.

1. The solubility of mannite in alcohol-water mixtures, containing 0, 20, 40, 60, 80 and 100 per cent. of ethyl alcohol, has been determined at 0, 15, 25, 35, 50 and 60°.

2. Within the temperature range studied, the logarithm of the solubility of mannite in mixtures of ethyl alcohol and water at any temperature is a function of the solubility in pure water, the mole fraction of alcohol present in the solvent and the absolute temperature; while at a particular temperature, it is a function of the solubilities in the pure components and the mole fractions of these components.

Swarthmore, Pennsylvania,
March 1, 1923.

Measurements of the Aurora of March 22-23, 1920. CARL STOERMER. (*Comptes Rendus,* January 8, 1923.)—On March 22-23, 1920, there occurred an aurora of the first order in respect to extent and splendor. It was accompanied by violent magnetic perturbations and by the passage of a large group of sun spots, and was characterized by the length of its rays and the variety of its colors.

Several rays situated above the Shetland Islands and Trondhjem were photographed from stations a long distance apart. The length of the base assures the accuracy of the results deduced. The upper ends of the rays were computed to lie from 550 to the enormous height of 750 km. above the earth. Later in the night other rays were photographed. Their lower ends were calculated to be elevated above the earth by distances never less than 100 km. and ranging from 100 to more than 300 km. Along those rays of which the lower ends were more than 120 km. above the earth there was not much change in brightness, but along those rays having their lower ends at a height from 100 to 120 km. above the earth the lower part was much brighter than the upper portions. "This is well explained by the hypothesis that the composition of the air changes rapidly in this interval from an atmosphere of nitrogen below to one of helium and hydrogen above." The lower border of one auroral drapery was not more than 85 km. above the earth. It reached 16 km. upwards.

The elevations here given are in striking contrast to data published in early volumes of *Nature* according to which two companions in high latitudes had streamers of the aurora flickering between them as they walked. G. F. S.

Cells with Fluorescent Liquid. A. GRUMBACH. (*Comptes Rendus,* January 8, 1923.)—Two platinum electrodes in a fluorescent solution constitute an electric cell when one of them is illuminated. In 1908 Goldman experimented on such cells, using saturated solutions of the fluorescent solute. He noted an electromotive force only upon illumination of the electrode. The present experimenter, however, using dilute solutions gets the effect in a different way. The cell was kept in the dark. A portion of the solution was exposed for two hours to the light from a mercury arc which had been filtered through a layer of water. Then one c.c. of this liquid was introduced into the cell near one of the electrodes. Immediately an electromotive force manifested itself and in its decay with time followed the curves got when an electrode was directly illuminated with subsequent removal of the light. The author interprets this as proving that the seat of the effect is not at the surface of the electrode.

When a solution of uranine was used, .05 g. per 100 g. water, the illumination of an electrode at first made it negative. The electromotive force grew larger and larger with the passage of time until after 21½ minutes it amounted to 8.2 millivolts. At the end of 40 minutes, the illumination continuing, the same electrode had become positive with an e.m.f. of 11 millivolts. This rose with increasing slowness until after 133 minutes it amounted to 100 millivolts. Then the cell was put in the dark, where the e.m.f. continued to rise for several minutes. It later diminished. G. F. S.

The Absence of Oxygen and Water-vapor from the Spectrum of Venus. C. E. ST. JOHN and S. B. NICHOLSON. (*Astrophys. J.,* December, 1922.)—It has been commonly assumed that Venus has an atmosphere resembling that of our earth in the possession of both oxygen and water, but recently the correctness of this belief has been questioned.

When the spectrum of Venus is photographed there are found dark lines due to oxygen. It is known that there is oxygen in the atmosphere of the earth and this would by itself produce such oxygen lines. The problem is to make the oxygen of Venus, if it really exists, write its autograph on the plate in an unimpeachable manner. The Mount Wilson astronomers accomplished this by taking their photographs at a time when the earth and Venus have such a relative velocity that the shift of the Venus lines corresponding to the Doppler effect amounted to .268 Å toward the violet, "an amount sufficient to separate completely the terrestrial components from those of Venus." The same reasoning applies to the search for water lines. "No trace of any line due to the planet's atmosphere was observed. It is estimated that in the path traversed by the solar light through Venus' atmosphere there must be less than the equivalent of one metre of oxygen, less than one-thousandth of that in our atmosphere, and less than one millimetre of perceptible water-vapor." G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

UNITED STATES GOVERNMENT SPECIFICATION FOR DRY CELLS.[1]

THIS circular contains specifications for dry cells, flashlight batteries, and radio B batteries. The dimensions of the standard sizes are given, followed by a discussion of standard tests and the minimum required performance for each of the standard sizes. Dry cells in excess of 100,000,000 are used annually in this country, and, although certain sizes have predominated, a large number of relatively unimportant sizes have been made. In an effort to standardize the more important sizes the Bureau of Standards called a conference of the leading manufacturers and largest individual users of dry batteries to meet with representatives of the various government departments in December, 1921. The conference considered seventeen different sizes of dry cells, and standardized seven of these sizes. It considered thirty different sizes of flashlight batteries and adopted eight of these as standard. It considered assembled batteries of the larger cells for ignition and similar work of which there are approximately thirty different sizes being made at the present time, and adopted six of these as standard. Two sizes of batteries for use with radio apparatus were also standardized. It is expected that the elimination of many sizes for which there is little demand, and which will no longer be considered standard, should result in considerable saving in the cost of manufacture and increase the convenience to the public.

A description of the manufacture and electrical characteristics of dry cells has been published in the second edition of Circular 79 of the Bureau of Standards.

SOAP.[2]

[ABSTRACT.]

THIS circular contains a brief discussion of the general composition of soap and of the most important varieties of soap commonly used, together with an outline of certain manufacturing

* Communicated by the Director.

[1] Circular No. 139, price five cents.

[2] Circular No. 62, price five cents.

procedures. Detailed specifications, including methods of sampling and testing, are given for special grade laundry soap, hard water laundry soap, and milled toilet soap.

PROPOSED SPECIFICATION FOR SPECIAL GRADE LAUNDRY SOAP.

This specification was prepared by the soap committee of the soap section of the American Specialty Manufacturers' Association in coöperation with a technical committee of the Federal Specifications Board, and is considered satisfactory for the grade of soap indicated. This specification has not been recommended for adoption as a government standard as there appears to be no demand at this time for soap of this kind in the government service. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by the Soap and Soap Products Committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a high-grade, well-made, uniformly mixed laundry soap, made from soda and fats; free from or with only a relatively small proportion of rosin; low in matter insoluble in alcohol; free from objectionable odor; and suitable for use with soft water for general cleaning and laundry purposes. Bidder shall state size, weight and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 34 per cent. Deliveries which yield more than 34 per cent. of volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol, and sodium chloride shall not exceed 5 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.2 per cent.

Matter insoluble in water shall not exceed 1 per cent.

Rosin shall not exceed 20 per cent.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constit-

uents will be calculated on the basis of material containing 30 per cent. of matter volatile at 105° C.

The material will be purchased by net weight, provided the matter volatile at 105° C. does not exceed 30 per cent. With deliveries containing more than 30 per cent. but not exceeding 34 per cent. of matter volatile at 105° C., settlement will be made on the basis of 30 per cent. of matter volatile at 105° C., *i.e.*, seven-tenths of a pound of non-volatile matter shall be considered one pound of soap.

PROPOSED SPECIFICATION FOR HARD WATER GRADE LAUNDRY SOAP.

This specification was prepared by the soap committee of the soap section of the American Specialty Manufacturers' Association in coöperation with a technical committee of the Federal Specifications Board, and is considered satisfactory for the grade of soap indicated. This specification has not been recommended for adoption as a government standard as there appears to be no demand at this time for soap of this kind in the government service. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by the Soap and Soap Products Committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a well-made, uniformly mixed laundry soap, made from soda and fats of which not less than 20 per cent. shall be coconut oil; free from rosin; free from objectionable odor, and suitable for use with hard water for general cleaning and laundry purposes. Bidder shall state size, weight, and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Color to match that of sample submitted for color only.

Matter volatile at 105° C. shall not exceed 44 per cent. Deliveries which yield more than 44 per cent. of volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol, and sodium chloride shall be not less than 8 per cent. nor more than 20 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 1 per cent.

The acid number of the mixed fatty acids prepared from the soap shall not be less than 205.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 38 per cent. of matter volatile at 105° C.

The material will be purchased by net weight, provided the matter volatile at 105° C. does not exceed 40 per cent. With deliveries containing more than 40 per cent. but not exceeding 44 per cent. of matter volatile at 105° C., settlement will be made on the basis of 40 per cent. of matter volatile at 105° C., *i.e.*, six-tenths of a pound of non-volatile matter shall be considered one pound of soap.

PROPOSED SPECIFICATION FOR MILLED TOILET SOAP.

This specification was prepared by the soap committee of the soap section of the American Specialty Manufacturers' Association in coöperation with a technical committee of the Federal Specifications Board, and is considered satisfactory for the grade of soap indicated. This specification has not been recommended for adoption as a government standard as there appears to be no demand at this time for soap of this kind in the government service. The specification gives the general requirements and detailed methods of sampling and testing, the preparation of the reagents required, and the basis of purchase. The methods of sampling and testing were prepared by the Soap and Soap Products Committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a high-grade milled cake soap, as free as possible from water; either colored or uncolored and unscented or perfumed in a manner indicated in the contract; thoroughly saponified; well compressed in firm, smooth cakes of a size and shape specified in the contract. It should lather freely when used with cold water. Bidder shall state weight and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 15 per cent. Deliveries which yield more than 15 per cent. of volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol, and sodium chloride shall not exceed 1.5 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.1 per cent.

Matter insoluble in water shall not exceed 0.1 per cent.

Unsaponified saponifiable matter shall not exceed 0.1 per cent.

Rosin, sugar, and foreign matter shall not be present.

The color, odor, and character of soap must be as specified by the purchaser.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 15 per cent. of matter volatile at 105° C.

The material will be purchased by net weight.

ELECTRICAL CHARACTERISTICS AND TESTING OF DRY CELLS.[2]

THIS circular is a revision of the circular bearing the same title, which was issued by the Bureau of Standards, April 25, 1919. It includes decisions of the conference of leading battery manufacturers, representatives of government departments, and a few of the largest individual users of dry cells and flashlight batteries, which met at the Bureau of Standards on December 5, 1921. The object of this conference was to consider the standardization of sizes of dry cells and the revision of specifications for them. The circular also includes much additional data on the performance of dry cells which has been obtained since the first edition of the circular was issued.

The theory and construction of dry cells are discussed. Zinc in contact with a solution of ammonium chloride becomes negatively charged because of the departure of positive zinc ions from its surface. As the zinc dissolves during the discharge of the cell, zinc ions, ammonia, and hydrogen ions are produced. A mixture of ground carbon and manganese dioxide serves as the cathode

[2] Circular No. 79, second edition, price fifteen cents.

and depolarizer for the cell. This becomes positively charged, for which several explanations are offered. The zinc serves as the container for the cell and as an anode. The electrolyte consists of a water solution of ammonium chloride and zinc chloride, and it is held partly in an absorbent material that lines the zinc container and partly in the mixture of carbon and manganese dioxide. The electrolyte is therefore unspillable, which fact has given rise to the common designation " dry cell."

There are several different methods of construction. The most familiar method used in making the larger sizes of dry cells in this country is the so-called paper-lined method. Before the cell is filled with the depolarizing mixture a lining of pulp board is placed inside the can. After this the depolarizing mixture is tamped into the cell around the carbon rod, and the protruding part of the pulp board lining is folded down over the top of the mixture. After this the cell is sealed. Another familiar method of construction is found in the so-called " bag type " cells which are commonly made in Europe and are typical of the small flashlight type of cells made in this country. A carbon rod with a surrounding mixture of carbon and manganese dioxide is wrapped in muslin and tied with a string, forming a unit which can be placed in the zinc can leaving sufficient space between the two for the electrolyte in the form of a paste. Other methods of construction which are less commonly used are also described in the circular.

The large size of dry cells, of which the most familiar example is the cell 2½ inches in diameter by 6 inches in height, may be subdivided according to the class of service for which it is intended. There are the ignition or heavy service cells, the telephone or light service cells, and an intermediate class, which is commonly designated " general purpose cells." Fundamentally, these are all of the same general type of construction, but they embody features which make them peculiarly suited to the class of service for which they are designed. The so-called ignition cells are intended for use in ignition of internal combustion engines and other service requiring considerable current. The telephone cells are intended for light intermittent service, including bell ringing and similar work. Assembled batteries consist of two or more cells combined to form a unit for which certain voltages and types of battery are now recognized as standard. Flashlight batteries

contain cells which are commonly of the bag-type construction. There are three different types of flashlight batteries that are considered standard. These contain standard sizes of flashlight cells of which there are five. Besides these there are desiccated, partially assembled cells and several other forms that are found on the market.

The circular discusses the electrical characteristics of dry cells beginning with a description of the behavior of dry cells in a circuit and the influence which the internal resistance of the dry cells has upon its performance. Curves are shown for the increase in internal resistance during discharge. When dry cells are used in groups, it is desirable to arrange the group in such a way as to secure the most economical service. Two factors are involved. The first is the voltage requirement and the other the current requirement. When an arrangement of cells involving series and parallel connection is required, a choice arises in the method of connecting them, a series of parallel connected cells generally being preferred.

The effect of temperature on the open-circuit voltage of dry cells is small and for most purposes can be neglected entirely. The effect of temperature on the maximum current which the cell can deliver is an increase of approximately 1 ampere for each 3° C. rise in temperature. Heat produces deterioration of dry cells in two ways. It tends to produce leakage, and it increases the rate of chemical reaction including local action taking place within the cell. It is therefore desirable to keep the cells when in storage in a cold place. The effect of temperature on the service capacity of the cells is marked, and tables are given in the circular showing the variation in the duration of service which may be obtained under varying conditions of discharge.

Since dry cells are generally used in circuits on which the resistance is constant or nearly so, the capacity is usually expressed as the number of hours or days that the cell will continue to give service on such a circuit. The capacity of dry cells may also be expressed in terms of ampere-hours or watt-hours. The circular includes extended tables showing the capacity for standard makes of the No. 6 size of dry cells discharging through fixed resistances and at constant current rates to various cut-off voltages. It is found that for any cut-off voltage the efficiency rises to a maxi-

mum as the resistance of the discharge circuit increases to about 100 ohms, but after this the efficiency falls off abruptly.

The standard tests for dry cells are described, and in an appendix specifications are given for dry cells, including all of the common types. These specifications emphasize the conditions which the cells must meet under test, but do not include manufacturing details.

A STUDY OF COMMERCIAL DIAL MICROMETERS FOR MEASURING THE THICKNESS OF PAPER.[4]

By Paul L. Houston and D. R. Miller.

[ABSTRACT.]

CONTROVERSIES frequently arise between the paper manufacturer or jobber and the consumer with regard to the thickness of paper. The cause of such controversies is usually traced to a difference in the readings of the instruments used in determining the thickness. Several types of dial micrometers are used in measuring paper. A study was made of the mechanism of a number of common types of dial micrometers to determine the effect of design on the performance and accuracy. Measurements were made of the static contact pressure and area and parallelism of the contacts. To determine the friction a measurement was made of the force required to move the mechanisms from rest towards increased readings of the pointer and the force that would just prevent movement towards decreased readings. One-half the difference between the force required to move the mechanisms to higher readings and prevent movements towards lower readings is evidently the friction of the mechanisms.

The total average contact pressure varies at a reading of 0.10 inch on different instruments from approximately 1½ ounces to over 11 pounds. Although the area of the plunger foot or contact is comparatively large for the higher total contact pressure, still the pressure per square inch varies from 2 to 43 pounds per square inch at the 0.10 inch reading. The friction of the mechanisms varied from a fraction of an ounce for an instrument with light moving parts and low contact pressure to over 3 pounds for an instrument with heavier parts and high pressure. In no instance was the plunger foot or contact parallel to the anvil over the

[4] Technologic Papers, No. 226, price ten cents.

whole surface to 0.0001 inch, that is, to one-tenth of the smallest graduation on the dial.

In two of the instruments, the required multiplication is obtained by two moving parts. In one of these the plunger carries a pin which engages with and causes rotation of a worm, to the end of which the pointer is rigidly fastened. The other instrument has a nut integral with the plunger, and a rotating screw engaged with the nut carries the pointer. The mechanisms vary from two moving parts to four moving parts. In the most common types of dial micrometers, the plunger is provided with a rack which engages with a train of gears or gear sectors. The pointer is fastened to the staff of the last gear in the train. The mechanisms of the instruments are illustrated diagrammatically and the number, length, and diameter of the bearings and the number and direction of action of the springs in each instrument is shown.

To determine if the variations in contact areas and contact pressures found had any bearing on the variation in values of thickness of paper obtained with various instruments, a performance test was made on nine micrometers. In this test fourteen different papers were used. To eliminate variation in the samples, thirty readings of the thickness of each paper were made with each micrometer. The readings of the instruments were corrected for errors found by comparison with standard steel thickness gages. Tables are given showing the average thickness of each paper as obtained with each micrometer and the deviation of the thickness of each paper obtained on each micrometer from the mean thickness as obtained by all the micrometers.

To show how the various papers are affected by the variation in contact areas and pressure represented by these nine micrometers, the total variation or difference between the highest average and lowest average value is shown for each paper. This total variation varies from 0.0003 inch for a high machine-finish writing paper 0.0025 inch thick, to 0.0010 inch for a sized and supercalendered ledger paper, 0.0065 inch thick. The machine-finish printing papers also show a high total variation when measured with this set of instruments. One of the instruments gave average values for the papers equal to or greater than the average obtained with all instruments. Two instruments gave average values equal

to, or less than, the average obtained with all instruments. The other micrometers show variations both plus and minus.

To further investigate the effect of contact areas and pressure on the measured thickness of the papers, a test was made of the compressibility of the papers with different sized contacts and various contact pressures with an instrument especially designed for the purpose. Curves are given showing the micrometer readings on each of the fourteen papers for three different contacts and total contact pressures, varying from 7 to 79 ounces. The reading of thickness showed variations of 0.0010 inch to 0.0015 inch between the low pressure (7 ounces) and the largest contact (0.314 square inch) and the highest pressure (79 ounces) and the smallest contact (0.0785 square inch).

A study of the results on the performance test and compression test shows that the same readings cannot be obtained with different contacts even if the same pressure per square inch is used. It is necessary then, to use both a standard contact and a standard contact pressure to obtain consistent results. To avoid difficulties in obtaining and retaining parallel contacts, it is suggested that the upper contact be made slightly convex.

The effect of design of the mechanisms on the friction, contact pressure, accuracy, and performance of the instruments is discussed, and specifications are laid down for a standard instrument. These specifications do not limit the standard instrument to any particular design, and it is felt that several of the types of mechanisms studied can be employed in instruments that will meet the specifications. This paper also contains specifications for procedure in determining the mean thickness of a sample of paper.

WAVE-LENGTH MEASUREMENTS IN THE ARC SPECTRA OF GADOLINIUM AND DYSPROSIUM.[5]

By C. C. Kiess.

[ABSTRACT.]

IN this article are presented wave-length data derived from a measurement of the arc spectra of Gd and Dy from about 5500 A. in the green out into the infra-red. Spectrograms of very pure gadolinium oxide and dysprosium oxalate, prepared at the Univer-

[5] Scientific Paper, No. 466, price five cents.

sity of Illinois, were made with the large concave grating spectrograph of the Bureau of Standards. In addition to these plates, there were available for measurement, several spectrograms made by Prof. J. M. Eder of the gadolinium and dysprosium salts separated by C. Auer von Welsbach. The wave-length data not only confirm the results of the chemists in separating the compounds in a very pure state from the original materials, but give, also, an accurate description of the spectra in regions that have hitherto been only incompletely investigated. The two tables of wave-lengths contain, respectively, about 950 lines observed in the arc spectrum of gadolinium, and about 800 lines for dysprosium. This work completes the investigation of the original assignment of material from the University of Illinois. Two previous papers give similar data for yttrium, lanthanum, and cerium, and for neodymium and samarium.

FURTHER TESTS OF STELLAR RADIOMETERS AND SOME MEASUREMENTS OF PLANETARY RADIATION.[8]

By W. W. Coblentz.

[ABSTRACT.]

THE present investigation was undertaken for the purpose of obtaining measurements of the thermal radiation emitted from a planet as a result of warming of its surface by exposure to solar radiation, including heat radiated by virtue of a possible high internal temperature of the planet itself, and also selectively reflected solar radiation of long wave-lengths. It is shown that the latter is probably small and negligible in comparison with the radiation emitted as a result of heating by solar radiation.

By comparing the transmission of the direct solar radiation, through a 1-cm. cell of water, with the transmission of the radiation emanating from the planet, a measurement is obtained of the intensity of the planetary radiation.

Radiometric measurements were made on Venus, Mars, Jupiter, Saturn, and the Sun, and in cases where similar measurements had been made at Mt. Hamilton, California, in 1914, the data were found in good agreement.

The radiometric measurements of the water-cell transmissions of the radiations from Jupiter and from the Sun were practically

[8] Scientific Paper No. 460, price ten cents.

the same indicating (1) that the outer atmosphere of Jupiter does not become sufficiently heated to emit long wave-length infra-red radiation, and (2) that any radiation emanating from its interior is entirely trapped by the surrounding atmosphere.

The intensity of the planetary radiation increases with decrease in the density of the surrounding atmosphere, and (as interpreted from the water-cell transmissions) in percentage of the total radiation emitted, is as follows: Jupiter (0), Venus (5), Saturn (15), Mars (39) and the Moon (80).

The intensity of the planetary radiation from the northern hemisphere of Mars was found to be less than from the southern hemisphere. This is to be expected in view of the observed cloudiness over the northern hemisphere which is approaching the winter season and hence is at a lower superficial temperature.

In Appendix I, measurements are given of the spectral energy distribution and the temperature of the sun as determined by means of a series of transmission screens placed in front of the stellar radiometer. The data obtained verify previous measurements indicating stellar temperatures ranging from 3000° K. for red, class-M stars, to 12,000° K. for blue, class-B stars.

COMPOSITION, PURIFICATION AND CERTAIN CONSTANTS OF AMMONIA.[1]

By E. C. McKelvy and C. S. Taylor.

[ABSTRACT.]

THE work presented in this paper forms a portion of that undertaken by the Bureau of Standards on the determination of the physical constants of materials used as refrigerating media, many of which have already been determined and published for ammonia, namely, specific heat of the liquid, latent heat of vaporization, specific volume of liquid, and vapor pressure. This paper deals mainly with the methods of purification and the tests for purity of the samples used in the determination of the various thermodynamical properties of ammonia, and gives assurance that the material used was of high purity.

An investigation was made of the composition and testing of commercial liquid ammonia. Analyses showed the presence of the following impurities: Non-condensing gases, water, pyridine,

[1] Scientific Paper, No. 465, price ten cents.

acetonitrile, ammonium acetate, and volatile materials containing carbon. Quantitative tests on eight standard American brands of commercial ammonia indicated the presence of less than 0.1 per cent. of impurities. Similar tests on three brands of German origin showed a somewhat larger percentage of impurities.

The best commercial samples were chosen as a starting point for further purification. It was found that water could be very completely removed from liquid ammonia by contact with metallic sodium in the form of fine wire. Numerous fractional distillations were found to remove most other impurities except the dissolved non-condensing gases. Difficulty was experienced in removing the latter gases, but by subliming the ammonia vapor into a container immersed in liquid air or by freezing the liquid into small crystals by its own evaporation, the content of non-condensing gas was found to be very materially reduced. Fifteen samples were prepared by five different methods for use in the physical measurements. Samples were prepared which contained: less than 0.003 per cent. by weight, of water, which was the limit of the chemical test applied; less than 1 part in 1,000,000, by volume, of non-condensing gases, and less than 0.01 per cent. of other impurities.

The density of solid ammonia was determined at −79 and −185° C., as 0.817 and 0.836 g./cm.^{3}, respectively. The freezing point was found to be −77.70° C., and the vapor pressure at that temperature, 45.2 mm. of mercury.

SPECIFIC VOLUME OF SATURATED AMMONIA VAPOR.[8]

By C. S. Cragoe, E. C. McKelvy and G. F. O'Connor.

[ABSTRACT.]

SEVERAL years ago the Bureau of Standards began the determination of the various thermodynamic properties of ammonia to establish an experimental basis for engineering tables to be used in the refrigerating industry. The present paper is the last of a series of papers on the determination of those properties under saturation conditions.

The specific volume, or the numerical reciprocal of density, of the saturated vapor was measured in the temperature interval −50 to +50° C. by two methods: One a direct method and the other

[8] Scientific Paper, No. 467, price five cents.

an optical method. Ammonia of high purity was used in all of the measurements.

The first method involved a direct determination of the mass of the vapor contained in a known volume, using three calibrated glass picnometers. Both phases, liquid and vapor, were present and in equilibrium. A correction was made for the mass of the liquid, using the results obtained from a separate determination of the specific volume of the liquid (already published). The vapor was superheated about 0.1° C. in order to prevent condensation taking place on the walls of the picnometers. The effect of adsorption was studied by introducing into the picnometers a large number of thin-walled glass tubes, thereby increasing the surface area about ten times. The results indicated that the effect of adsorption was no greater than the inherent inaccuracies of the method.

In the second method the refractive index n of the vapor was measured, using a Fizeau-Pulfrich interferometer, and the specific volume u' was calculated from the Gladstone and Dale relation, $u'(n-1)=$ constant. The constant in this relation was determined from the mean of several measurements of the specific volume and refractive index of the vapor at 0° C. and 760 mm. pressure.

The specific volume was calculated at various temperatures by means of the Clapeyron equation, $L=\theta(u'-u)dp/d\theta$, using the experimental results previously obtained at this bureau for the latent heat of vaporization L, the specific volume of the liquid u, and the slope of the vapor-pressure temperature curve $dp/d\theta$. Above 0° C. the measurements by the two methods are in fair agreement with the calculated values, differing at most by about 0.3 per cent. At lower temperatures the results found by the direct method are systematically lower and those found by the optical method are systematically higher than the calculated values, amounting to about 2 per cent. at −50° C. These systematic differences are believed to be due, in the direct method, to a thin film of liquid on the walls of the picnometers above the surface of the liquid, and to an adsorbed film of gas on the interferometer plates in the optical method.

Since the results by the two methods differ from the Clapeyron values in opposite directions and by about the same amount, the latter were chosen as the most probable values. The final results

are represented by the empirical equation $\log_{10} u' = 1939.0331/\theta - 32.06611 + 10.704105 \log_{10} \theta + 0.0862366 \sqrt{406.1 - \theta} + 0.002667 (406.1 - \theta)$ in which u' is expressed in cm.$^3/g$ and θ in degrees absolute (° abs. = ° C. + 273.1).

TENTATIVE STANDARD TEST METHODS AND PERCENTAGES OF OIL AND MOISTURE IN HAIR PRESS CLOTHS.[9]

By F. R. McGowan and C. W. Schoffstall.

[ABSTRACT.]

PRESS cloth is a heavy textile fabric usually 13 inches in width and ranging up to ½ inch in thickness. It is used in the oil-pressing industries in the presses for extracting the oil from the pulpy matter. Since it undergoes a pressure of approximately 2000 lb./in.^{2}, a strong, resilient fibre is required, which makes it desirable to use hair fibres, such as camel hair, human hair, horse hair, or goat hair.

The material is bought on a weight basis so that the oil, which is added to permit the use of efficient manufacturing processes, and the moisture are important items. The methods are outlined for determining these percentages. The petroleum-ether method for extraction of oil is given. The sample is placed in a Soxhlet tube and extracted for five hours, after which the solvent is evaporated and the percentages are obtained. A means of distinguishing between the quantities of mineral and fatty oil is given. The method of obtaining moisture content is the usual one of obtaining weight as received and then drying and obtaining bone-dry weight.

The standards suggested are: Moisture, 11 per cent.; oil, 5 per cent.; water-soluble material, 2½ per cent.

SHELLAC.[10]

By Percy H. Walker and Lawrence L. Steele.

[ABSTRACT.]

A DESCRIPTION is given of the source, manufacture, uses and common methods of testing shellac. It is shown that the generally accepted iodine value method for determining rosin in flake shellac may be subject to very large errors, and this method can not be

[9] Technologic Paper, No. 231, price five cents.

[10] Technologic Paper, No. 232, price five cents.

applied to cut shellac. The amount of material soluble in a light petroleum distillate and the acid number of this material are shown to be quite constant for pure shellac, and a method of determining adulteration, both by rosin and other substances which can be as easily applied to cut shellac as to flake shellac, has been developed. Suggested specifications for pure orange flake shellac and orange shellac varnish are given.

Properties of Rochelle Salt Related to the Piezo-electric Effect. JOSEPH VALASEK. (*Phys. Rev.*, Dec., 1922.)—A rod of crystalline quartz cut in a certain manner develops on its two ends electrical charges of opposite kinds when it is stretched. Other crystals also exhibit this piezo-electric effect, but not too much is known about its cause. The recent development of a telephone based on this phenomenon makes it desirable to learn more. Rochelle salt, a double tartrate of sodium and potassium, shows the effect and shows it in such a manner as to present itself as a tempting mark for the experimenter, for an increase of temperature from −20° to −10° C. makes its piezo-electric modulus become more than five times as great as at the lower temperature, while an increase from 20° to 30° C. reduces the modulus from 8.1 to 1.08. The mode of attack was to vary the temperature and to study the corresponding changes in physical properties. No unusual type of variation was found in the cases of refractive index, thermal expansion, specific rotatory power of an aqueous solution and reversible electro-optic rotation. Speaking of the electrical resistance the author says: "Between −20° and +30° C., however, it was found to depend on the direction of the current, being only one-half as great in one direction as in the other at 0° and at 20°." "In view of the fact that none of the properties measured show changes with temperature which correspond with those of the piezo-electric effect, it is probable that the elastic or piezo-optic constants must change in such a way as to account for the piezo-electric changes." G. F. S.

Positive-ray Analysis of Potassium, Calcium and Zinc. A. J. DEMPSTER. (*Phys. Rev.*, Dec., 1922.)—With slight improvements the method of his previous researches was used. Confirming Aston's results, potassium was found to have two isotopes of atomic weights 39 and 41, the intensity ratio of the two being about 18 to 1. This relation would give 39.1 for the mean atomic weight of ordinary potassium. Calcium gave two isotopes of atomic weights 40 and 44, the former being 70 times as strong as the latter. The four isotopes of zinc gave atomic weights of 64, 66, 68 and 70. The last of these appears in only a small quantity. G. F. S.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE SIZE-FREQUENCY DISTRIBUTION OF PARTICLES OF SILVER HALIDE IN PHOTOGRAPHIC EMULSIONS AND ITS RELATION TO SENSITOMETRIC CHARACTERISTICS. III.[1]

By E. P. Wightman, A. P. H. Trivelli and S. E. Sheppard.

An improved method of studying microscopically the size-frequency distribution of silver halide in a photographic emulsion is given in detail, together with an estimate of the principal sources of error in the method. Frequency curves and data are given for a number of typical emulsions ranging from the slowest to the fastest. It has been found that an exponential equation of the form $Y = Y_0 e^{-kx}$ fits some of the data very closely, while for other data another, a Gaussian equation of the form $Y = Y_0 e^{-k(x-d)^2}$, can be used to express the distribution of sizes, Y being the frequency per 1000 and x the size of the grains. The distribution of total area of grains in each case per unit area of plate, together with the variation in class size is more important photographically than the simple frequency distribution. It is obtained by multiplying each side of the above equation by the factor $N/1000.X$, in which N represents the total number of grains per square centimetre of the plate. Empirical sensitometric characteristics for these emulsions were also determined and are summarized in tabular form for comparison with the frequency data. The data show definitely that the relative speed of the emulsions increases rapidly with the increase of average size of the grains contained therein. Of the other characteristics, no definite statement can be made since these depend much more on the variation of other factors in the preparation and coating of the emulsions.

* Communicated by the Director.

[1] Communication No. 148 from the Research Laboratory of the Eastman Kodak Company and published in *J. Phys. Chem.*, February, 1923, p. 141.

THE SIZE-FREQUENCY DISTRIBUTION OF PARTICLES OF SILVER HALIDE IN PHOTOGRAPHIC EMULSIONS AND ITS RELATION TO SENSITOMETRIC CHARACTERISTICS. IV.[1]

By E. P. Wightman, A. P. H. Trivelli and S. E. Sheppard.

THE existence of statistical variation of sensitivity among silver halide grains is discussed. For photolysis in a homogeneous system, a mathematical expression is developed relative to the density-exposure function and has the formula $D' = -\ln[e^{-D_m} + (1 - e^{-D_m})\, e^{-k'I_a t}]$. The relation of statistical variation of inertia to the density-exposure function will correspond with the inertia-variation function. Conditions permitting this correspondence are noted. If the size-frequency corresponds with the sensitive-frequency then the curve of "reciprocity size-frequency" gives the inertia-variation curve; integration of this, the density-exposure function. For the most general case where $dD/D_m - D = k'dE$ and $k = f(i)$ or a function of inertia, the integration gives $D = D_m\ (1 - e^{-\mu})$ where $\mu = D_m/k'(1 - e^{-k'E}).E$ is the exposure and D_m the maximum density.

AN INSTRUMENT (DENSITOMETER) FOR THE MEASUREMENT OF HIGH PHOTOGRAPHIC DENSITIES.[2]

By Loyd A. Jones.

IN this paper a densitometer, designed for the measurement of very high densities, is described. In the earlier part of the paper the essential requirements of instruments of this type are considered and the principles used in some of the well-known instruments for this purpose are discussed. Following this a detailed description of the new instrument is given.

The high intensity of illumination on the density being measured is obtained by imaging, at a magnification of unity, the filament of a locomotive headlight lamp on the diffusing element in contact with which the sample is placed. The intensity of the

[1] Communication No. 153 from the Research Laboratory of the Eastman Kodak Company and published in *J. Phys. Chem.*, January, 1923, p. 1.

[2] Communication No. 160 from the Research Laboratory of the Eastman Kodak Company and published in *J. Opt. Soc. Amer.*, March, 1923, p. 231.

comparison beam is controlled primarily by an adjustable sector shutter placed in a collimated beam of light between two elements of one of the lens combinations used to form an image of the light source on the comparison target. The photometric field is obtained by the use of the well-known Lummer-Brodhun cube. In addition to the adjustable sector diaphragm, a rotating sector disc is used for reducing the intensity of the comparison beam. Diaphragms consisting of perforated metal plates may also be introduced for control of the intensity. The adjustable sector diaphragm was calibrated on the photometer bar, utilizing the inverse square law as a means of varying the intensity in a known manner. The results show that the scale readings are directly proportional to the intensity to well within the photometric limit. While the previous instruments used for measuring density fail to produce satisfactory results on densities greater than 3.0, this instrument functions satisfactorily up to densities of 8.0. The sensitometric curve of a material exposed to X-rays was determined and found to be similar to the characteristic curves of the same material when exposed to white light except that the maximum density was found to be approximately 6.0 in the case of the X-ray exposure instead of 3.0 in the case of the exposure to white light.

PRELIMINARY NOTE ON THE SPECTRAL ENERGY SENSITIVITY OF PHOTOGRAPHIC MATERIALS.[1]

By Loyd A. Jones and A. L. Schoen.

THE paper contains an account of preliminary measurements made to determine the amount of energy of various wave-lengths required to produce a definite photographic effect. The radiation from a tungsten ribbon filament lamp was dispersed by means of a quartz monochromatic illuminator. The photographic plate (Seed 30) was exposed for a known time, the energy density at the exposing plane being measured by means of a high-sensitivity thermopile and galvanometer. The plate was then developed to a gamma of unity and the resultant density measured. From the data obtained, the energy density in ergs per square centimetre required to give a density of unity when developed to a gamma

[1] Communication No. 166 from the Research Laboratory of the Eastman Kodak Company and published in *J. Opt. Soc. Amer.*, March, 1923, p. 213.

of unity was computed for various wave-lengths. These values are also expressed in terms of quanta per square micron. These values (quanta per square micron) vary from 280 at $\lambda = 460\mu\mu$ up to 450 at $\lambda = 400\mu\mu$.

Analysis of the Energy Distribution in Speech. I. B. CRANDALL and D. MACKENZIE. (*Bell System Tech. J.*, July, 1922.)—Of the making of applications of the vacuum tube amplifier there is truly no end. Here it is used to get the total energy record of the voice speaking a sentence and at the same time a second tube in a resonant circuit provides the energy record of a range of vibration frequencies existing in the same spoken sentence. By adjusting the latter circuit the energy contribution of each of twenty-three frequencies contained in the speech was obtained for four men and two women. The greatest energy for three of the men was found for frequencies near 150, while the maximum for the fourth was at about 500. The maxima for the women occurred, of course, at somewhat higher frequencies than for the three men. One woman's voice contained considerable energy in the component of frequency 2000. With this exception no frequency higher than 1300 contributed anything notable to the energy integral.

From another point of view these experiments are of interest in leading to this conclusion, "We may take 125 ergs per second as the total sound energy flow from the lips with the normally modulated voice." It thus becomes clear that a member of the Senate of the United States using this type of voice could filibuster for an entire day with the expenditure of less than a single foot-pound of energy.

G. F. S.

The Theory of Probabilities Applied to Telephone Trunking Problems. E. C. MOLINA. (*Bell System Tech. J.*, November, 1922.)—A number of problems in machine switching are solved. They can in general be reduced to equivalent problems in throwing dice. Some idea of the importance attached to this type of problem in practice may be inferred from the fact that a study was made of 100,000 calls in order to settle a point in question.

"Machine switching development, therefore, gave a great impetus to the application of the theory of probabilities to telephone engineering and in the Bell System work along this line has been in progress, systematically, for many years. The work has included not only the theoretical solution of many trunking problems, but has also involved the computation of special probability tables and collection of data by means of which theoretical results have been closely checked."

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

COLLECTION AND EXAMINATION OF EXPLOSIVE DUSTS.[1]

By L. J. Trostel and H. W. Frevert.

[ABSTRACT.]

A METHOD devised for measuring the dustiness of air should prove of practical value in determining the presence of explosive mixtures of dust in grain elevators and certain industrial plants.

Briefly, the scheme is to filter a measured volume of dusty air through a paper thimble, either by a calibrated hand pump or by a small, portable electrically driven blower, equipped with a Venturi meter and manometer.

The following information can thus be secured: (*a*) Solids per cubic foot of air; (*b*) particle size and composition; and (*c*) in heavy dusts, the "relative flammability," a standard laboratory explosibility test.

The device can be used on all the ordinary explosive dusts and under practically all plant conditions.

THE EFFECTS OF WATERPROOFING MATERIALS AND OUTDOOR EXPOSURE UPON THE TENSILE STRENGTH OF COTTON YARN.[2]

By H. P. Holman and T. D. Jarrell.

[ABSTRACT.]

UNBLEACHED and unsized warp yarn, treated with various waterproofing materials, was tested to determine its tensile strength and then exposed to the weather. At the end of one year the treated yarn in most cases was stronger than the untreated yarn similarly exposed, but weaker than the treated yarn before being exposed. Yarn subjected to three treatments containing asphalt showed no material loss in tensile strength after being exposed. Raw drying oils caused more deterioration than the same oils previously boiled with metallic driers. In most cases, semi-drying and non-drying oils caused as much deterioration as raw-drying oils. The addition of burnt umber to a drying-oil treatment had a decided preservative effect.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Ind. Chem.*, **15** (March, 1923) : 232.

[2] Published in *J. Ind. Eng. Chem.*, **15** (March, 1923) : 236.

INDUSTRIAL MOLD ENZYMES.[3]

By Kokichi Oshima and Margaret B. Church.

[ABSTRACT.]

THE supposition that fungi produce extracellular and intracellular enzymes is accepted provisionally. The extracellular enzymes can be obtained by percolating mature fungi with water, but the latter cannot be obtained by mere treatment with water. Some investigators have tried to get the intracellular enzyme from koji residue, a mold ferment grown on a large scale on some substratum, and the whole washed free from extracellular enzymes, by treating with many solvents. Negative results were always obtained. Experiments show that extracellular and intracellular enzymes are the same, and after a certain period of growth all enzymes are excreted. Many investigators have shown the same results with other fungi. In the present investigation the work was quantitative, and the ratio of exo- and endo-enzymes during the cultivation of *A. oryzæ* and *A. flavus* was found.

Soon after spore formation almost all enzymes have been excreted into the culture media. The increase and decrease of enzymes in the mycelium is quite rapid, but in the culture medium it is quite slow. It is doubtful whether the excretion of enzymes is due to the autolysis of the mycelium, because at the time of the most rapid excretion of enzymes the weight of mycelium is increasing and the maximum amount of exo-enzyme occurs simultaneously with the maximum quantity of mycelium. In experiments intended for the study of the influence of culture media, etc., on the production of mold enzymes, therefore, the estimation of the enzymes produced in the mycelium is an incorrect method of procedure, particularly when it is realized that through differences in culture media the rate of growth and the time of sporing may be varied.

Power Losses in Insulating Materials. E. T. HOCH. (*Bell System Tech. J.*, November, 1922.)—The author shows that in insulators the power loss is measured by the product of the phase difference by the dielectric constant. This product varies but little for good insulators over a large range of voltages and frequencies. Pyrex glass seems to have, of all materials investigated, the lowest power loss, while phenol fibre has the greatest. The change of the loss with temperature is very considerable. G. F. S.

[3] Published in *J. Ind. Eng. Chem.*, **15** (1922) : 1.

NOTES FROM THE U. S. BUREAU OF MINES.*

POWDERED COAL.

By John Blizard.

POWDERED coal has proved an economical fuel for steam raising, cement making, metallurgical furnaces, and many other purposes. For steam raising, with a properly constructed boiler and furnace, a continuous efficiency of over 80 per cent. may be maintained. For other purposes a high temperature with no regenerators may be maintained by using powdered coal, with less coal consumption than when using producer gas, stokers, or hand firing.

The unit system alone is economically applicable for small installations, where less than about ten tons a day are used.

For larger installations the multiple system, with Raymond or Fuller mills and with indirectly fired driers, seems to be preferable.

To distribute the coal, screw conveyers are recommended to convey large quantities of coal short distances, and either the Fuller-Kinyon pump or compressed air to convey it long distances.

The Quigley weighing tank is a valuable adjunct to the compressed air distribution.

The direct low-pressure system of distribution should be used solely to distribute coal short distances to small furnaces, where the cost and inconvenience of using separate bins and feeders for each furnace is unwarranted.

The foregoing summarizes the results of a study, made by the writer, of powdered coal plants in Canada and the United States. Further details are given in Bulletin 217 of the Bureau of Mines.

THE CHLORIDE VOLATILIZATION PROCESS.

By Thomas Varley.

THE art of treating ores by the chloride volatilization process is still in the experimental stage. The process has not been sufficiently developed along metallurgical lines to warrant a definite statement as to the exact place it will occupy in the industry. The basic theory of the process has received the attention of prominent

* Communicated by H. Foster Bain, Director.

metallurgists for twenty years, and considerable research and experimental work have been carried on.

If commercially utilized, the process will fill a long-felt want in metallurgy, especially in the treatment of oxidized and semi-oxidized or "carbonate" ores of copper, lead, and silver. Such ores are difficult to treat by gravity concentration or by flotation; in the former their tendency to slime upon crushing and their being of lower specific gravity than the sulphide minerals cause serious losses; in the latter much has been done in sulphidizing oxidized ores and subsequently recovering the artificial sulphides by flotation. Difficulties in proper sulphidizing and the low recoveries obtained have not balanced the cost of the treatment in many plants and in very few has it proved successful.

Evidently there is a big void to fill in the treatment of these ores. No radical changes in present methods are forecast, but it is obvious that chloride volatilization can have a distinct place as a method of treatment for ores that are not readily amenable to present methods. In many plants it might replace concentration methods, especially where part of the mineral content in the ores exists in forms other than sulphides.

Further details covering the experiments by the Bureau of Mines in coöperation with the University of Utah are given in Bulletin 211.

EFFECTS OF TEMPERATURE AND TIME OF DISTILLATION ON THE CRUDE OILS FROM OIL SHALE.

By Lewis C. Karrick.

THE amount and quality of oil that can be produced from any shale may be made to vary to an important degree by changing the temperature relations existing in the shale charge during destructive distillation. The rate at which the oil is formed from the shale is affected by the rate of heat supply, and therefore by the temperature of the shale during its thermal decomposition. The quality of the oil formed may be controlled by altering the temperature of the shale, and, therefore, the rate of formation of the oil. Variations in the yield and quality of shale oils may be caused by inherent properties of the retort used, but in any event the properties of the crude oil and yield are very largely the result of the extent to which the thermal decomposition has progressed.

Recognition of these principles will aid in explaining to a large degree the reasons for the wide variations in oils produced from the same shales by different "processes." These principles also may be applied in the operation of different types of retorts in order that crude oils of a type most profitable to the operator may be produced.

The Bureau of Mines has conducted an extended series of tests in the destructive distillation of oil shales, in order to determine the wide variations that may be effected in the quality and yield of shale oil by changing the rate and temperature at which the oil is formed. These tests furnished interesting information on the four related points: Yield of oil, quality of oil, temperatures required to distill shales, and time required for distillation.

The principal conclusions from these tests are:

(1) They indicate that the changes in the quality of crude shale oils, produced by varying the rate of distillation, may be due to (*a*) the temperature at which the decomposition took place, and (*b*) the extent to which the thermal reaction progressed.

(2) The temperature studies show conclusively that the oils produced in the slow rates of distillation are actually produced at much lower temperatures than the oils formed by rapid distillation.

(3) The practical limits to which controlled cracking within the retort may be carried are not yet determined, but since time or temperature are such important factors in the production of good crude shale oils, it should be feasible in commercial retort design to balance size of retort and heating surface, rate of heat supply to the shale, size of shale particles, and rate of throughput, so that the most desirable rate of distillation, and subsequent thermal reactions, can be obtained. Thus, it should be possible to govern, within fairly wide limits, the qualities of the crude oils obtained, and thereby to produce crude oils of the most desirable properties for commercial needs.

(4) Data of the nature presented in the curves, when obtained from similar tests made on other shales, will furnish a logical basis of comparing different shales.

Further details will be found in Serial 2456 of the Bureau of Mines.

Acoustic Wave Filters. G. W. STEWART. (*Phys. Rev.*, December, 1922.)—Filters for light and for electric waves are known. Why, one wonders, have sound filters been so long delayed? It is true that Helmholtz resonators act as filters when the small opening is placed at the ear, but it has remained for this eminent investigator in the field of acoustics to investigate the theory of sound filters and to devise filters that embody his results. He has made and tested three kinds of filters. "The low frequency pass filter will give approximately zero transmission at all frequencies above, and fairly good transmission below a certain predetermined frequency. The high frequency filter will transmit above a minimum frequency. The single-band filter will transmit a group of frequencies. . . . In these filters, the cutoffs are not sharp and the performances are not exactly as just stated."

"Low frequency pass filters were made, for example, by two concentric cylinders joined by walls equally spaced and perpendicular to the axis. Each chamber thus formed had a row of apertures in the inner cylinder which served as the transmission tube. In one case the volume of each chamber was 6.5 cm.^{3}; the radius of the inner tube, 1.2 cm.; the length between apertures, 1.6 cm. A chamber and one such length of inner tube is called a section. Four such sections were found to transmit 90 per cent. of the sound from zero to approximately 3200 d.v. where the attenuation became very high, resulting in zero transmission up to 4600 d.v. where transmission again appeared." There is manifestly an error in the printed article, for, where the author gives 90 per cent., as just quoted, the table of results gives but .9 per cent.

The filtering action of such sections is ascribed to interference. It is suggested that the filters will be found to have applications, not only in the laboratory but in connection with the phonograph and in wireless telephony, with the megaphone and loud-speaking devices. The design of musical instruments may later be affected. "In wireless telegraphy an acoustic filter makes possible the simultaneous reception of an indefinite number of messages with the same antenna."

G. F. S.

The Range of Alpha-particles from Polonium in Various Gases. C. W. VAN DER MERWE, University of Cape Town. (*Phil. Mag.*, Feb., 1923.)—The range was determined by C. T. R. Wilson's method of photographing the tracks caused by the particles in damp air suddenly expanded. In moist air at normal temperature and pressure the range was found to be 3.59 cm., whereas Geiger found is to be 3.58 cm. by a different method. The range in hydrogen is 16.28 cm. and in methyl bromide only 1.76. In all the cases examined there is a close agreement of the ranges of the particles from polonium with similar determinations made by Bragg using radium A and radium B as sources of the rays. A fine series of ten photographs of the tracks is appended. G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 18, 1923.)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, April 18, 1923.

MR. W. C. L. EGLIN, Vice-president, *in the Chair*.

The Board of Managers submitted its report. The report recorded the election to membership of:

H. D. Arnold, Esq., Ph.D., Research Engineer, Western Electric Company, 463 West Street, New York City, New York.

Charles A. D. Burk, Esq., B.S., Inventor, Atlantic City, New Jersey.

Miss Marion Reilly, A.B., 2015 DeLancey Place, Philadelphia, Pennsylvania.

Charles Burton Thwing, Esq., Ph.D., Physicist, 3339 Lancaster Avenue, Philadelphia, Pennsylvania.

W. W. Trench, Esq., Assistant Secretary, General Electric Company, Schenectady, New York;

lectures before the Sections as follows:

"Radiation and Chemical Reaction" by
Herbert S. Harned, Ph.D.,
Assistant Professor of Chemistry,
University of Pennsylvania,
Philadelphia, Pennsylvania;

"Physical Measurements of Audition and Their Bearing Upon the Theory of Hearing" by
Harvey Fletcher, Ph.D.,
Research Laboratory,
American Telephone and Telegraph Company and
Western Electric Company, Incorporated,
New York City, New York;

"The Theory of Light and Vision" by
James P. C. Southall, A.M.,
Professor of Physics,
Columbia University,
New York City, New York;

and a lecture before the Stated Meeting, March 21, 1923, by
Harvey C. Hayes, Ph.D.,
Research Physicist,
U. S. Navy,
on "Measuring Ocean Depths by Acoustical Methods";

a course of lectures on
"The Electron in Chemistry" by
Sir Joseph John Thomson, O.M., F.R.S., LL.D., Ph.D., D.Sc.,
Master of Trinity College,
Cambridge, England,

on the afternoons of April 9th to 13th, inclusive; also the following additions to the library, 103 bound volumes, 12 unbound volumes, 75 pamphlets and 2 drawings.

The Chairman then announced that the next business of the meeting would be the presentation of the awards made by the Institute on recommendation of its Committee on Science and the Arts and recognized Mr. W. H. Fulweiler, who introduced Dr. Albert W. Hull, to whom was awarded the Howard N. Potts Medal for his paper on "The Crystal Structure of the Common Elements" which appeared in the JOURNAL of the Institute for February, 1922. Mr. Fulweiler said:

"Mr. Chairman, Members of the Institute, Ladies and Gentlemen: Following its custom, your Committee on Science and the Arts has reviewed all of the papers published in the JOURNAL of the Institute during the year 1922 with a view to determining whether any of these papers possess such special merit as would warrant recognition by the Institute.

"As a result of such an inquiry, your Committee has selected the paper entitled 'The Crystal Structure of the Common Elements,' by Dr. A. W. Hull of the Research Laboratory of the General Electric Company, this paper appearing in the February number of the JOURNAL for 1922, as being of such special character as to be worthy of the Howard N. Potts Medal.

"This medal is the highest award available to the Committee and is given for papers of the first importance that have appeared in the JOURNAL of the Institute. In his paper, Doctor Hull has recorded the results of research that has extended over a number of years.

"As is well known, the investigation of the crystal structure involves the use of X-rays and Doctor Hull has not only developed a new method of attack—the powder method which gives at a single exposure the reflection from all possible crystal faces—but has also developed apparatus which enables the observations to be made almost automatically, thus greatly conserving the operator's time and attention.

"Doctor Hull also made very valuable suggestions as to methods of interpreting the observations. This subject is still so new that aside from its great theoretical interest, the practical applications are as yet undeveloped. It will undoubtedly find application in the study of alloys, in the failure of metals under stress and the study of the magnetic properties of ferrous metals.

"Mr. Chairman, I have the honour to present to you Albert Wallace Hull, Doctor of Philosophy, of the Research Laboratory of the General Electric Company of Schenectady, New York, to receive from you the Howard N. Potts Medal for his paper on 'The Crystal Structure of the Common Elements.'"

The Chairman presented the Medal and Certificate to Doctor Hull, who thanked the Institute for the high honour conferred upon him.

Mr. Fulweiler was again recognized and described the universal measuring machine made by the Société Genevoise d'Instruments de Physique, to whom had been awarded the Edward Longstreth Medal. He said:

"Mr. Chairman, Members of the Institute, Ladies and Gentlemen: It seems particularly appropriate that The Franklin Institute Devoted to Science and the Mechanic Arts and located in Philadelphia, workshop of the world, should give recognition to the perfection of apparatus that is of fundamental importance in the control of precision in manufacturing operations.

"After a careful and thorough investigation, your Committee on Science and the Arts has recommended the award of the Edward Longstreth Medal to the Geneva Society of Geneva, Switzerland, for its universal measuring machine. This medal is awarded for particularly meritorious improvements and developments in machines and mechanical processes.

"The increasing demand for accuracy in manufacturing machines and machine parts calls for precision in workmanship and this depends not only upon the skill of the workman, but also upon the accuracy and invariability of measuring apparatus used in the process of manufacture.

"Until recently, the micron, one-thousandth of a millimetre or about one-half of one ten-thousandth of an inch, has been considered as useful only in scientific measurements. To-day it has become a practical unit of measurement in those industries where the very highest degree of accuracy is required.

"Practical measurements depend upon the use of standard and limit gauges and in order that these measurements may be accurate, it is essential that the gauges should be of the proper size when made and that suitable means shall be available in order to determine that these dimensions are retained. This naturally requires the development of accurate standard means for making these measurements, and it is for such a purpose that the apparatus that is the subject of this award, which is known as the Universal Measuring Machine, has been devised.

"The Universal Measuring Machine was developed by the Geneva Society for the purpose of furnishing a machine by means of which it is possible to determine absolute lengths of a gauge or piece of work to within one-millionth of an inch. A variety of auxiliary apparatus is provided whereby either internal or external measurements may be made and also the necessary chucks, etc., which permit the measuring of the pitch of screw threads.

"Your Committee has made a series of tests to verify the accuracy of the main screw thread of this instrument by referring to the ultimate physical standard of length, that is, the wave-length of monochromatic light. These experiments were made with a Fabry and Perot interferometer and the results verify the very high degree of accuracy claimed for the apparatus by the Geneva Society.

"Mr. Chairman, I have the honour to present to you Mr. Roy Y. Ferner, the American Representative of the Geneva Society of Geneva, Switzerland, to receive from you on their behalf the Edward Longstreth Medal."

The Chairman presented the Medal, Certificate and Report to Mr. Ferner, who said:

"As the American Representative of the Société Genevoise d'Instruments de Physique, I am sure of their appreciation of the honour conferred upon them in the bestowal of these evidences of recognition of the value of their work in the development of this Universal Measuring Machine. The honour is of added significance in that the Société Genevoise, a company having many years' experience in the manufacture of scientific apparatus, is honoured by this for the development of a machine adapted to the needs of production manufacturing—in particular, for providing means for the direct reference of all measuring equipment used in a manufacturing plant to one standard of length, thus securing greater uniformity and accuracy in products which are dependent upon length measurements.

"The practical application of the exact sciences to the needs of industry must accompany development in science. It is for this that The Franklin Institute stands. In this instance we see the application of several researches of the International Bureau of Weights and Measures. The encouragement of such developments by these awards of your Institute is very valuable. They benefit industry, they give added zest to the researches of the scientist, and they reward the medium of the application of these researches to industry. On behalf of the Société Genevoise d'Instruments de Physique, I thank you."

The paper of the evening on "The Cathode-ray Oscillograph and Its Application to the Exact Measurement of Explosion Pressures, Potential Changes in Vacuum Tubes, and Magnetos" was then presented by D. A. Keys, Ph.D., Department of Physics, McGill University, Montreal, Canada. A description was given of the special form of cathode-ray oscillograph devised during the war by Sir J. J. Thomson, O.M., for use in conjunction with the piezo-electric properties of crystals to measure the very rapid and large variations of pressure due to an explosion in water. The method consists in placing in the water near the explosion, a special form of crystal detector which transforms the pressure variations into corresponding changes in electrical charge by virtue of the piezo-electric properties of the crystals. These electrical variations act upon a beam of moving electrons which are magnetically controlled in the oscillograph, and this beam falling directly on a photographic plate traces out the time-pressure history of the explosion. The arrangement is thus a pressure recording device of negligible inertia and is the only method known of determining exactly the maximum pressure in water produced by an explosion of gun-cotton, T. N. T. or other high explosive. With this form of oscillograph changes which take place in one fifty-thousandth of a second have been measured. Among the many possible applications of this instrument to physical and engineering investigations, mention was made of recent work on the rise of potential in vacuum tubes at the beginning of the discharge. The same scheme may be used in the study of specific heats of gases at high temperatures and in the investigation of the characteristics of a magneto.

The subject was illustrated by lantern slides and experiments.

After a discussion, a rising vote of thanks was extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, April 4, 1923.)

HALL OF THE INSTITUTE,
PHILADELPHIA, April 4, 1923.

MR. W. H. FULWEILER *in the Chair.*

The following report was presented for final action:

No. 2798: Way Adjustable Hinge.

The following reports were presented for first reading:

No. 2797: Merill Process of Industrial Heating by Oil Circulation.

No. 2805: Ives' Photometric and Radiometric Researches.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 1, 1923, at eight o'clock, with Dr. George A. Hoadley in the Chair. The minutes of the previous meeting were read and approved.

Edwin F. Northrup, Ph.D., member of the Institute, delivered a lecture on "High Temperature Investigation," in which a description was given of the methods and technic used in the study of matter at high temperature, free from chemical contamination.

The paper, which was illustrated by means of lantern slides and an ironless induction furnace, was discussed at length; a vote of thanks was extended to Doctor Northrup; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 8th, at eight o'clock, with Dr. Thomas D. Cope in the Chair.

The paper of the evening on "Ionization and Resonance Phenomena" was presented by Dr. Charles B. Bazzoni, Professor of Experimental Physics, University of Pennsylvania, Philadelphia, Pa. The speaker pointed out that the modern theories of atomic structure in which the properties of materials are related to the grouping of electrons in the atoms are to a large extent checked experimentally by determinations of ionization and resonance potentials. These quantities are intimately connected with the structure and stability of the atoms and with the production of the ordinary optical spectra.

The speaker also outlined briefly the development of the dynamic theories of atomic constitution including recent refinements. Certain experimental methods used to investigate the stability of the atomic and molecular systems were described and discussed, and finally the way in which the production of spectral series depends upon the electronic arrangements was brought out. A non-technical statement of the state of our knowledge in this rapidly changing field was made by the lecturer. The subject was illustrated by lantern slides.

After a brief discussion, a rising vote of thanks was extended to Doctor Bazzoni. Adjourned.

T. R. PARRISH,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 15, 1923, at eight o'clock, with Dr. H. J. M. Creighton in the Chair. The minutes of the previous meeting were read and approved.

Herbert S. Harned, Ph.D., Assistant Professor of Physical Chemistry in the University of Pennsylvania, delivered an address on "Radiation and Chemical Reaction." The photochemical nature of all chemical reactions was discussed from the viewpoint of mathematics

The communication was discussed; a vote of thanks was tendered to Doctor Harned; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 29, 1923, at eight o'clock, with Dr. James Barnes in the Chair. The minutes of the previous meeting were read and approved.

Harvey Fletcher, Ph.D., Research Laboratories of the American Telephone and Telegraph Company and the Western Electric Company, Incorporated, New York City, delivered a lecture upon "Physical Measurements of Audition and Their Bearing upon the Theory of Hearing." A comprehensive summary was given of the results obtained by the use of the vacuum tube and high-quality telephone transmitters and receivers in making measurements in audition.

The communication was discussed at length; a vote of thanks was extended to Doctor Fletcher; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

THOMSON LECTURES.

SIR JOSEPH JOHN THOMSON, O.M., F.R.S., LL.D., Ph.D., D.Sc., Franklin Medallist, Honorary Member of the Institute, Master of Trinity College, Cambridge, England, delivered a series of lectures on "The Electron in Chemistry" in the Hall of the Institute on the afternoons of April 9th to 13th, inclusive.

The first lecture was delivered on the afternoon of April 9th at 3.30 o'clock. Dr. Walton Clark, President of the Institute, welcomed Sir Joseph and Mr. W. C. L. Eglin, Vice-president of the Institute and member of its Board of Managers, presided. The following is a brief synopsis:

The atomic theory had little effect on the progress of chemistry as long as nothing was known about the structure of the atom. The discovery of the electron showed that atoms have a structure and gave a clue to its character. The arrangement of the electrons in the atom. Number of electrons in the atom. Electronic isomers. Active nitrogen. Instability of configuration when electrons are too crowded. Eight the maximum number of electrons which can be on the outer layer of an uncharged atom. This result involved a periodicity in the properties of the atoms of the different elements such as is expressed by Mendeleef. Periodic law. Valency. The size of atoms. Specific inductive capacity. Work required to abstract an electron from an atom. Methods for testing the configuration of electrons in an atom.

Dr. Arthur L. Day, Director, Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C., M.F.I., presided at the second lecture on Tuesday, April 10th. Attention was given to the following:

The combination of atoms to form molecules. Physical interpretation of chemical "bonds." Double bonds. Union of two similar atoms to form a molecule. Union of two or more dissimilar atoms. "Positive and negative" valencies. Arrangement of electrons in octets. Comparison with the results of

the old valency rules. Stability of systems of octets. Instability chains of octets in general. Stability of CH_2 chains. Polar molecules. Importance of these in chemical reactions. Problem of the water molecules. Arrangement of the electrons in chlorides, chlorates, perchlorates, carbonates, sulphates, sulphites, nitrates, nitrites. Connection between the arrangement of the electrons and the acidic or basic properties of the compound.

Dr. A. A. Noyes, Director of Chemical Research, California Institute of Technology, Pasadena, California, presided at the third lecture on Wednesday, April 11th. Special attention was given to the following:

Mechanism of chemical combination. Active molecules. Their occurrence in such reactions as the combination of hydrogen with chlorine or of oxygen with hydrogen. Afford a physical basis for Thiele's theory of partial valencies. "Molecular compounds." "Residual affinity." Double salts. Electron theory gives a physical basis for Werner's coördination theory. Mechanism of electrolytic dissociation. Structure of the ions in liquids. Catalytic action. Variable valency and homologous elements.

Dr. Joseph S. Ames, Director of the Physical Laboratory, The Johns Hopkins University, Baltimore, Maryland, M.F.I., presided at the fourth lecture given on Thursday, April 12th. The following topics were considered:

Connection between variable valency and the magnetic properties of the elements. Magnetism of chemical compounds. Magnetism of oxygen. Diamagnetism affords a method of checking the configuration of the atom and the migration of the electrons in chemical combination. The electron theory of solids. General considerations. Calculation of the energy of a solid.

The closing lecture of the series was given on Friday afternoon, April 13th. Dr. Augustus Trowbridge, Professor of Physics, Princeton University, Princeton, New Jersey, M.F.I., presided. The following topics were considered:

The calculation of the electron theory of the compressibility of the elements in a solid state. Critical periods of vibration for solids. Latent heat of evaporation. Compressibility and specific inductive capacity of salts. The structure of metals, salts and insulators. Electrical conductivity of metals.

Individuals and groups, physicists and chemists, from the research laboratories of the great electrical manufacturing and electricity supply companies and from institutions of learning from nearly every state of the Union and Canada were in attendance.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 18, 1923.)

HONORARY MEMBERS.

GENERAL G. FERRIÉ, Inspecteur des Services de la Telegraphie, Militaire et des Transmissions, 51 bis, Boulevard Latour-Maubourg, Paris, France.

DR. A. A. MICHELSON, Department of Physics, University of Chicago, Chicago, Illinois.

RESIDENT MEMBERS.

MISS MARION REILLY, 2015 DeLancey Place, Philadelphia, Pennsylvania.
DR. CHARLES BURTON THWING, 3339 Lancaster Avenue, Philadelphia, Pennsylvania.

NON-RESIDENT.

DR. H. D. ARNOLD, Engineering Department, Western Electric Company, New York City, New York.
MR. CHARLES A. D. BURK, Atlantic City, New Jersey.
MR. W. W. TRENCH, The General Electric Company, Schenectady, New York.

CHANGES OF ADDRESS.

MR. C. P. BOWER, 11 Eastern Avenue, Wyndmoor, Montgomery County, Pennsylvania.
MR. FRANK H. BREWSTER, 118 Bedford Avenue, Buffalo, New York.
MR. WILLIAM J. BURGESS, 940 South 55th Street, Philadelphia, Pennsylvania.
MR. BENJ. J. DASHIELL, Dunkirk P. O., Calvert County, Maryland.
MR. JOHN M. HAMMOND, 14 East Abington Avenue, Chestnut Hill, Philadelphia, Pennsylvania.
MR. ALLEN HAZEN, 23 West Forty-third Street, New York City, New York.
MR. ERNST JOHANSEN, New England Oil Refining Company, Fall River, Massachusetts.
MR. FRANK H. STEWART, 4416 North Fifteenth Street, Philadelphia, Pennsylvania.
MR. FRANK M. TAIT, Callahan Bank Building, Dayton, Ohio.

NECROLOGY.

Sir James Dewar, The Royal Institution, London, W. I., England.
Mr. R. C. M. Hastings, The International Telephone Company, Columbus, Ohio.
Mr. A. B. Stitzer, Republic Engineers, Inc., 60 Broadway, New York City, New York.

LIBRARY NOTES.

PURCHASES.

American Electrochemical Society—Transactions, 1921. 1922.
BACON, R. F., and HAMOR, W. A.—American Fuels, Ed. 1, 2 vols. 1922.
CAIN, J. C.—Manufacture of Dyes. 1922.
CLAYTON, W.—The Theory of Emulsions and Emulsification. 1923.
COOKE, T., AND SONS, LTD.—Adjustment and Testing of Telescope Objectives 1921.
GILDEMEISTER, E.—Volatile Oils, vol. 3. 1922.
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HAMILTON, H.—Scientific Treatise on Smoke Abatement. 1917.
PARTINGTON, J. R., and PARKER, L. H.—Nitrogen Industry. 1923.

Royal Society of London—Catalogue of Scientific Papers, vols. 16–17. 1918, 1921.

STRUBEN, A. M. A.—Tidal Power. 1921.

Tables Annuelles de Constantes et Données Numériques 1913–16, 2 vols. 1921–22.

Who's Who. 1923.

Year Book of Wireless Telegraphy and Telephony. 1922.

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Aldrich Pump Company, Aldrich Pumps. Allentown, Pennsylvania, 1922. (From the Company.)

Alexander Milburn Company, Catalogue of Carbide Lights. Baltimore, Maryland, 1921. (From the Company.)

Alfred University, Catalogue 1922–23. Alfred, New York. (From the University.)

Allis-Chalmers Manufacturing Company, Electrically Driven Saw Mills. Milwaukee, Wisconsin, 1922. (From the Company.)

Alloy Welding Processes, Limited, Bulletins 32, 38, 40 and 42. London, England, no date. (From the Company.)

American Sheet and Tin Plate Company, Pamphlets on Corrosion of Steel and Copper. Pittsburgh, Pennsylvania, no date. (From the Company.)

American Woolen Company, List of Woolen Mills and Pamphlet, "From Wool to Cloth." Boston, Massachusetts, 1921. (From the Company.)

Amherst College, Catalogue 1922–23. Amherst, Massachusetts. (From the College.)

Atlas-Imperial Engine Company, Incorporated, Catalogue 22, Atlas-Imperial Diesel Engines. Oakland, California, 1922. (From the Company.)

Beaumont, R. H., Company, Bulletin 61, Beaumont Skip Hoist for All Bulk Materials. Philadelphia, Pennsylvania, 1922. (From the Company.)

Bridgeport Brass Company, Bulletin No. 15, Brass Pipe and Piping. Bridgeport, Connecticut. (From the Company.)

British Thomson-Houston Company, Limited, Electric Drive in Textile Mills. Rugby, England, 1922. (From the Company.)

Brooke Tool Manufacturing Company, Limited, Brooke Engineers Small Tools, 1920. Birmingham, England, 1920. (From the Company.)

Brown Hoisting Machinery Company, Catalogue L, Drop-forged Chain for Conveyors and Elevators. Cleveland, Ohio, 1922. (From the Company.)

Buffalo Forge Company, Catalogues Nos. 205, 700 and 800. Buffalo, New York, 1922. (From the Company.)

Cadman, A. W., Manufacturing Company, Catalogue of Valves. Pittsburgh, Pennsylvania, no date. (From the Company.)

Cameragraph Company, The Book of Cameragraph. Kansas City, Missouri, 1922. (From the Company.)

Canada Department of Mines, Thirty-first Annual Report and Bulletin No. 6, Irrigation Practice and Water Requirements for Crops in Alberta. Ottawa, Canada, 1922. (From the Department.)

Carling Turbine Blower Company, Carling Turbine Blower Bulletin No. 50. Worcester, Massachusetts, 1922. (From the Company.)

Carnegie Institution of Washington, Year Book No. 1. Washington, District of Columbia, 1922. (From the Institution.)

Carpenter, P., A Companion to the Improved Phantasmagoria Lantern. London, England, 1835. (From Mr. John J. L. Houston.)

Chase Companies, Incorporated, Chase Condenser Tubes. Cleveland, Ohio, 1922. (From the Corporation.)

City Parks Association of Philadelphia, Thirty-third Annual Report. Philadelphia, Pennsylvania, 1921. (From the Association.)

Cole, Marchent and Morley, Limited, Pamphlets Nos. 70, 69, 66 and Catalogue No. 56 of Tram Cars and Brakes. Bradford, England, no date. (From the Company.)

College of the City of New York, Catalogue 1922–23. New York City, New York. (From the College.)

Columbia College, Catalogue 1921–22. Dubuque, Iowa. (From the College.)

Columbia Machine Works, Catalogue of the Works, 1892 to 1922. New York City, New York, 1922. (From the Works.)

Columbia University, Catalogue 1922–23. New York City, New York. (From the University.)

Concordia College, Catalogue 1921–22. Moorhead, Minnesota. (From the College.)

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Crescent Machine Company, Crescent Wood-working Machinery. Leetonia, Ohio, 1922. (From the Company.)

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Glasgow Electrical Engineering Company, Limited, Natural Power Electricity from the Wind. Glasgow, Scotland, no date. (From the Company.)

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Hillsdale College, Catalogue 1921–22. Hillsdale, Michigan. (From the College.)

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Kansas State Geological Survey, Bulletins 7 and 8. Lawrence, Kansas, 1921. (From the State Geologist.)

Keystone Telephone Company, Booklet on Automatic Telephones. Philadelphia, Pennsylvania, no date. (From the Company.)

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Lang, John, and Sons, Limited, Catalogue of Lathes and Booklet, Lang Surfacing and Boring Lathe. Johnstone, Scotland, 1922. (From the Company.)

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Manchester Steam Users' Association, Memorandum by Chief Engineer for the Year 1921. Manchester, England, 1922. (From the Association.)

Marquette University, Catalogue 1922–23. Milwaukee, Wisconsin. (From the University.)

Massachusetts Institute of Technology, Directory of Officers and Students, 1922–23. Cambridge, Massachusetts, 1922. (From the Institute.)

McGill University, Catalogue 1922. Montreal, Canada. (From the University.)

Michell Bearings, Limited, Michell Viscometer. Newcastle-on-Tyne, England, no date. (From the Company.)

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Nevada Department of Mines, Annual Reports for 1910, 1913–14, 1915–16 and 1917–18. Carson City, Nevada. (From the Department.)

New South Wales Department of Mines, Mineral Resources Note No. 31, Bulletin No. 1 and Records of the Survey. Sydney, New South Wales, 1921 and 1922. (From the Department.)

New York University, Catalogue 1922–1923. University Heights, New York. (From the University.)

Niagara Machine and Tool Works, Bulletin No. 51. Buffalo, New York, 1923. (From the Works.)

Nicholson, Peter, The Student's Instructor. New York City, New York, 1837. (From Mr. John J. L. Houston.)

BOOK REVIEWS.

THE ORIGIN OF SPECTRA. By Paul D. Foote and F. L. Mahler, Physicists, U. S. Bureau of Standards (American Chemical Society Monograph Series). 250 pages, illustrations, plates, 8vo. New York, Chemical Catalog Company, Inc., 1922. Price, $4.50.

By a judicious mixture of classical mechanics and the quantum theory Bohr in 1913 proposed a very illuminating and suggestive explanation of the Balmer, Lyman and Paschen series in the spectrum of hydrogen. Since then Bohr with many co-workers has developed the theory to explain many other properties of the other elements besides hydrogen. In this field of work the authors of this book have contributed a large amount of valuable experimental work especially with regard to the ionizing and resonance potentials of the elements.

The book is divided into eleven chapters, namely, The Quantum Theory of Spectroscopy, Energy Diagrams, Ionization and Resonance Potentials for the Elements, Line Absorption Spectra of Atoms, Line Emission Spectra of Atoms, Cumulative Ionization, Thermal Excitation, Thermochemical Relations, X-ray Spectra, Photo-electric Effect in Vapors, Determination of h involving Line Spectra.

It is impossible to give short concise statements of the many important observations discussed in these chapters and the writer accordingly strongly recommends the book to chemists and physicists who are interested in the structure and mechanics of the atoms of the different elements.

The authors of the book are to be complimented on having presented such a comprehensive and suggestive survey of this modern field of investigation which, no doubt, will be the foundation for future developments in theoretical and practical physical chemistry. JAMES BARNES.

INDEX GENERALIS (1822–23). General Year-book of the Universities. Published under the direction of R. de Montessus de Ballore, D.Sc., Professor in the Faculty of Sciences of Paris. 12mo, 2110 pages, paper bound. Paris, Gauthier-Villars et Cie. 50 Francs, net.

This work is intended to occupy the field that has long been occupied by the German "Minerva," the "Handbuch der gelehrten Welt." The war interrupted the publication of that work, and while it has now resumed issue, the French competitor has developed to a very large and comprehensive volume. The copy of the French publication now in hand is intended for English-speaking persons, but the general text is in French, and some portions of the specific descriptions are in the language of the country in which the institution is located. It would perhaps be better if the whole was in French. The vast majority of those who consult this work are able to read the text in that language, but business considerations must, of course, not be disregarded, especially in a work involving such expense. The value of such a work depends entirely upon the thoroughness with which the material has been gleaned and arranged. The present edition, a great improvement on the first, seems to have been carefully prepared and to cover all the necessary data. A glance

over its pages shows the enormous extension of school and college teaching and the vast array of men and women who are devoted to educational service. The book is well printed in clear, though necessarily small, type. It will be of great use in library work and the educational field.

HENRY LEFFMANN.

PRACTICAL PHYSIOLOGICAL CHEMISTRY, by Philip B. Hawk, M.S., Ph.D. Eighth edition, revised, 8vo, xvi–666 pages, index, two full-page plates in color, four additional full-page plates and 197 figures of which twelve are in colors. Philadelphia, P. Blakiston's Son and Company. $5 net.

Little is needed concerning this book, except to chronicle the appearance of the new edition, as it has been so long before the public and been received with great favor. In this edition introduction of new matter has compelled an increase of bulk, although some matter—become antiquated—has been deleted. The additions relate chiefly to blood, acidosis, quantitative analysis of urine, vitamins and determination of kidney function. The author directs special attention to Benedict's test for sugar and Folin's test for albumin, quantitative procedures that have been set forth in an addendum. It is believed that these mark a very important advance in the available procedures in urinary analysis. Acknowledgment is made to several persons who aided the author in this revision. It is interesting to compare this large octavo volume with the thin duodecimo books on clinical chemistry which fifty years ago sufficed as guide for the hospital laboratory—when there was one!

HENRY LEFFMANN.

INDUSTRIAL ORGANIC CHEMISTRY. By Samuel P. Sadtler, Ph.D., LL.D., and Louis J. Matos, Ph.D. Fifth edition, revised, enlarged and partly rewritten. xvi–667 pages, index and 141 illustrations, 8vo. Philadelphia, J. B. Lippincott Company, 1923. $8 net.

The first edition of this work was issued in 1891, when it promptly assumed a leading place in the field to which it was devoted. Treating comprehensively the wide field of applied organic chemistry, its popularity enabled the author to issue in comparatively rapid succession, revised editions, which was a great advantage in a book devoted to a department in which accumulation of data and modifications of methods were proceeding actively. The work has, therefore, been kept up to date. In the present edition, Doctor Sadtler has had the assistance of Doctor Matos, who has taken care of the chapters on textile fibres, coal-tar industries, bleaching and dyeing. These chapters involve much detail of the war-time chemistry, and the developments of that period have necessitated rewriting most of the text. The major portion of the book has been revised by the senior author. In his field, a large amount of new matter has been introduced in consequence of the enormous development of the industries relating to cellulose and its derivatives, and also the newer methods concerning fatty oils, especially the hydrogenation problems. The sections on statistics that have heretofore been included in the book have been dropped, as it is held that the U. S. Government reports furnish all the data required.

Chemical industries have taken an enormous development of late in English-speaking countries, on account of the problems arising out of the World War,

and a comprehensive work of this character, brought as this is up to date, will be of great value to the work-chemist. The mechanical execution of the book is excellent. HENRY LEFFMANN.

GENERAL SCIENCE, WITH EXPERIMENT AND PROJECT STUDIES. By George A. Bowden, B.S., University of Cincinnati. 622 pages, index and 334 illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1923. $1.68 net.

This book has somewhat larger scope than most of the works on general science that have appeared of late. The popularizing of science by means of lectures, journals and books has been going on for a number of years, gaining in volume and comprehensiveness each year. The object of science is the discovery of truth, and in strict construction of this definition, it is not necessary that the discovery should inure to the advantage of mankind, indeed, it may be said that some of the most recent striking applications of science have resulted in disadvantages. It is a question whether high explosives, asphyxiating gases, submarines and airplanes have not done more harm than good, and many would incline to put the automobile in the same category.

This book is intended to meet the modern demand for education along what may be termed practical lines. The swing of the educational curriculum from the old system in which the classics, mathematics, logic and homiletics dominated, has given curricula dominated by natural and physical sciences, vocational training, and the study of the relations of the human-being to the environment. Whether this transition will be of substantial advantage time alone will show, but teachers are not lacking who feel that pupils are being over-laboratoried and that a partial return to the drill methods of the older courses will be beneficial. The author states frankly that his book has been written to aid in bringing the student into direct contact with natural phenomena and objects that have real significance in life. In fact, he emphatically states the theme is "life" and particularly human life. A brief note on the development of the human race from its earliest period opens the book. It is doubtful if archeologists would endorse all the statements. Our knowledge of prehistoric man is very scanty, and it is unwise to set forth a series of statements in a dogmatic form, leading the student to believe that the data are established. In this preliminary note no account is taken of the extraordinary ability of drawing and painting attained by the cavemen in certain parts of Europe. The origin of language is also a problem of great difficulty. The book takes up the origin of the art of making fire and gives illustrations of the means used by existing savage peoples for making fire. An interesting account is given of the old tinder box, flint and steel, and an outline of the development of the manufacture of matches. In the paragraph on the use of phosphorus in matches, the word, by a curious typographic error, is six times spelled "phosphorous." Taking up the chemistry of fire, the preparation and properties of oxygen are described, but the directions are not at all commendable. No information is given as to the chemical change that occurs in heating the oxygen mixture, nor any suggestion as to the part that the manganese dioxide plays. It is true that the exact nature of this action is not known, but the student

should be informed of the reason for its addition. The student is directed to fill five bottles with oxygen, but is not told how much potassium chlorate to take to obtain a given volume of gas. The manner of mounting the test-tube is quite objectionable, and the pneumatic trough is merely academic, as no support for the collecting bottle is shown. At the present day when excellent illustrations of apparatus for experiments are available, such rude drawings are ridiculous. At the end of each section suggestions for practical problems are given under the title "Projects."

The book covers a wide field, much attention being given to hygienic problems. It is very liberally illustrated, mostly with creditable pictures but a few of those in the earlier portion are inferior. The text is interspersed with many questions, and the demonstrations are mainly adapted to classes provided with apparatus, for which reason one is more puzzled at the awkward arrangement of the apparatus for making oxygen. Taken all in all, however, a great deal of scientific information may be gathered from the book, and much useful advice concerning the problems of daily life will be found in it. The mechanical execution is good, and there is a fair index. HENRY LEFFMANN.

ORGANIC CHEMISTRY OR CHEMISTRY OF THE CARBON COMPOUNDS. By Victor von Richter. Edited by R. Anschütz and H. Meerwein. Vol. 3, heterocyclic compounds. Translated from the eleventh German edition, by E. E. Fournier D'Albe. xviii–310 pages and index. Philadelphia, P. Blakiston's Son and Company. Price, $6 net.

The appearance of the second volume of this work was noted less than a year ago, and what was then said will apply equally to the present volume. The book written by Victor von Richter many years ago reached a high degree of popularity in a short time and has since maintained its position. The original text has been kept up to date by the industry of Anschütz who, in the later period, has been assisted by Meerwein. The third volume completes the translation. Each of the three volumes has a separate index. These have been prepared with great care and it is probable that they are much superior to the indexes of the original, as it is generally known that Continental authors are not strong on indexing. The Germans, however, are doing a great deal better of late years than the French. The book contains an immense amount of matter well arranged and well displayed, and the immensity of the field of organic chemistry is well shown by an examination of the three volumes. It may be worth while considering whether the sub-title "Chemistry of the Carbon Compounds" is now necessary. HENRY LEFFMANN.

ULTRA-VIOLET RADIATION: ITS PROPERTIES, PRODUCTION, MEASUREMENT AND APPLICATIONS. By M. Luckiesh, Director of Applied Science, Nela Laboratories. 8vo, 249 pages, index and 12 plates. New York, D. Van Nostrand Company.

Here one may find interesting news from "outer darkness." Those rays, too rapid for our eyes to utilize, constitute one of the most attractive fields of study in physics. In the preface we are told that about one hundred and twenty years have elapsed since the discovery that the visible spectrum is but a small section of the range of vibrations. That the rainbow is due to some

action of the raindrops on light was surmised by Greek scientists, but knowing nothing of the composition of white light, no explanation of the phenomenon could be furnished. Newton's experiment, conducted with a beam of light of appreciable size, gave him a series of overlapping spectra, in which not only were the color distinctions more or less obliterated, but the dark spaces in the solar spectra were unseen. Wollaston observed these, but the mapping of the few very conspicuous ones was done by Fraunhofer, whose name is indissolubly attached to the series. Many years passed before the ultra-violet and infra-red rays were detected. Scheele in 1777 came very near detecting the former, but it was not until 1800 that Sir William Herschel observed the existence of infra-red radiations, and one year later, Ritter detected the ultra-violet. Much more attention seems to be paid to the study of ultra-violet rays than to the infra-red. This may be due to the much greater activity of the former. It was long known that the violet end of the spectrum is most active chemically both on inorganic matters and living tissues, and this gives a strong incentive to investigation, but the susceptibility of the standard photographic emulsions to these rays affords an easy means of determining the range and line spectrum of them. Wood has shown some interesting actions of infra-red, having among other effect discovered that when trees in full leaf are photographed through filters excluding all other rays, the leaves appear as if covered with snow. In the recent work of Palmer on plant pigments, mention is made of a practical application of the discovery that the green pigment of plants has a different emission relation from ordinary green paints, so that the painted canvas, intended to deceive aviators, could by means of light filters be distinguished from real foliage.

The book in hand contains a very large amount of information on that portion of "invisible light" that has shorter wave-lengths than can be appreciated by the human eye. We do not know whether any of the lower animals have a greater range, and it is useless to speculate upon the problem. One of the most striking features of the shorter wave-lengths in the stoppage of them by some common materials quite transparent to ordinary light. Glass, mica, celluloid and gelatin are of this nature. Quartz and fluorspar are different, transmitting a considerable portion of ultra-violet light freely, and thin films of the cellulose acetate, which is now used for certain classes of picture-film also seem to interpose but little resistance to those rays not far above the violet. The title of the book "Ultra-violet Radiation" is better than "Ultra-violet Light," although the latter is most usual. Ordinary humanity limits the word "light" to the form of energy that affects the human eye in a specific manner, just as "sound" is understood as referring to a class of waves that specifically affect the human ear. In both cases waves exist of similar nature to those respectively seen and heard, but not perceived by us. It may be laid down as a fundamental principle that if there were no eyes there would be no light, and if there were no ears there would be no sound. Light and sound, in the fundamental significance of those terms, are dependent on specific perception by certain sense organs.

Very little unfavorable criticism is developed in examining the book, but the tables of symbols for indicating the wave-lengths deserve some animadversion. There seems to be no reason for adopting m for μ. The latter arrangement has gone into general use, and the welter of units and symbols that has

been caused by the rapid progress in chemistry and physics, should lead the scientific world to say "anathema" to anyone who introduces an unnecessary datum or sign. Nor can the author escape disapproval for allowing the fact that the publisher wanted to economize, justify the use of A° for the correct method of writing the symbol of the unit now so largely used in expressing wave-lengths. It seems to the reviewer that it will be much better to drop the umlaut sign altogether, rather than attempt to retain it in a highly inaccurate and even misleading manner. "A°" means really "A degrees."

The book opens up a fascinating field of optics and the author has not only sifted the literature with care and thoroughness, but his own contributions to this and other departments of the science have been numerous and valuable. It is to be hoped that he will soon give us a book treating of the dark region at the other end of the spectrum. The work is a monograph and not an elementary text-book and we cannot expect, therefore, to have the apparatus and phenomena set forth in great detail, but in view of the interesting developments of the applications of these radiations, their powerful effects, especially on protoplasm, more space given to the description of the forms of apparatus now available for producing the rays and employing them would have been welcome, but after all the lists of dealers in the apparatus will probably afford sufficient information to those who having general experience in optics wish to enter upon work in this special field. The chapter on the action of the radiations upon living matter is of special interest to the biologist and clinician.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Institute for Government Research. Service monographs of the United States Government, No. 9. The Weather Bureau, its History, Activities and Organization, by Gustavus A. Weber. 87 pages, 8vo. Baltimore, The Johns Hopkins Press, 1922. Price, $1.

The Riddle of the Rhine, Chemical Strategy in Peace and War. An account of the critical struggle for power and for decisive war initiative. The campaign fostered by the great Rhine factories, and the pressing problems which they represent. A matter of preëminent public interest concerning the sincerity of disarmament, the future of warfare, and the stability of peace, by Victor Lefebure, with a preface by Marshal Foch, and an introduction by Field-Marshal Sir Henry Wilson. 282 pages, plates, 8vo. New York, E. P. Dutton and Company, 1923. Price, $2.

Géométrie Descriptive, par Gaspard Monge. Augmentée d'une Théorie des Ombres et de la Perspective. Extraite des papier de l'auteur par Barnabé Brisson. 2 vols, illustrations, 12mo. Paris, Gauthier-Villars et Cie., 1922. Price, 6 Francs.

American Engineering Standards Committee. Year Book, 1923. 48 pages, quarto. New York, Committee.

Les Théories de la Relativité dépassant les Données de l'Expérience, par le lieutenant-colonel corps. 43 pages, quarto. Paris, Gauthier-Villars et Cie., 1923. Price, 3 Francs 50.

Cours de Mécanique Céleste, par M. H. Andoyer. Tome I. 439 pages, 8vo. Paris, Gauthier-Villars et Cie., 1923. Price, 50 Francs.

The Association of British Chemical Manufacturers. Official directory of members with classified list of their manufactures. 319 pages, 8vo. London, Association, 1923. Price, 10 shillings, 6 pence.

Plant Physiology, by Vladimir I. Palladin. Authorized English edition edited by Burton Edward Livingston. Second American edition with a biographic note and chapter summaries by the editor. 360 pages, illustrations, portrait, 8vo. Philadelphia, P. Blakiston's Son and Company, 1923. Price, $4.

Metals and Their Alloys. A modern practical work dealing with metals from their origin to their useful application . . . by Charles Vickers. Partly based on the third edition of "Metallic Alloys," by William T. Brannt. 767 pages, illustrations, 8vo. New York, Henry Carey Baird and Company, Incorporated, 1923. Price, $7.50.

Interior Wiring and Systems for Electric Light and Power Service. A manual of practice for electrical workers, contractors, architects and schools, by Arthur L. Cook. Second edition, thoroughly revised. 458 pages, illustrations, plates, 16mo. New York, John Wiley and Sons, Incorporated, 1923. Price, $3.

Institute for Government Research. Service monographs of the United States Government, No. 17. The Federal Power Commission, its History, Activities and Organization, by Milton Conover. Baltimore, The Johns Hopkins Press, 1923. Price, $1.

Institut International de Physique Solvay. Atomes et Electrons. Rapports et discussions du Conseil de Physique tenu a Bruxelles du 1er au 6 Avril 1921 sons les auspices de l'Institut. Publiés par la Commission administrative de l'Institut et MM les Secrétaires du Conseil. 271 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1923. Price, in paper, 20 Francs.

Ontario Department of Mines: Thirtieth Annual Report being volume xxx, part I, 1921. 197 pages, illustrations, plates, 8vo. Toronto (Canada), King's Printer, 1922.

National Advisory Committee for Aeronautics: Technical Notes No. 127, The Air Propeller, Its Strength and Correct Shape, by H. Dietsius. 9 pages, plates, quarto. No. 128, Tests on an Airplane Model AEG D1 of the Allgemeine Elektricitäts Gesellschaft, A.-G., Airplane Construction Section. Conducted at the Göttingen Model testing laboratory for aerodynamics, by Max Munk and Wilhelm Molthan. 26 pages, plates, quarto. No. 130, Model Supports and Their Effect on the Results of Wind-tunnel Tests, by David L. Bacon. 8 pages, plates, quarto. No. 131, Variation in the Number of Revolutions of Air Propellers, by W. Achenbach. 7 pages, quarto. Washington, Committee, 1923.

General Science with Experimental and Project Studies, by Garfield A. Bowen. 634 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1923. Price $1.68.

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